VOL. VII, No. 4 DECEMBER, 1932

THE QUARTERLY REVIEW
of BIOLOGY

WHY ARISTOTLE INVENTED THE WORD ENTELECHEIA

BY WM. E. RITTER

FOREWORD

THE discussion here presented is rather long and involved. But should it win recognition as a substantial contribution to the subject treated it would, I believe, be justified.

The general undertaking of which these pages are a section should be thought of as a part of the "companion book" (Ritter, 1927, p. 324). A hint of the character of the undertaking is contained in the statement (p. v) of the work referred to, that the "other book" would have the title *The Natural Philosophy of our Conduct*.

Although I had got far enough into the problem of human activity as a phenomenon of nature five years ago to see the necessity of dealing with it both analytically (by natural science) and synthetically (by natural philosophy), the almost constant occupation with the problem since has led me to recognize that various subsidiary or seemingly detached problems are really not only inseparable from the main problem but are vital to it.

I fully accept, along with the vast majority of modern professional students of living nature, the theory that man with all his attributes is natural in whatever sense any other species of animal or plant is natural. This being so, I am led to conclude that we of this era are in position to understand the problem of human life more broadly and deeply than were those of any earlier era. And this I understand to be equivalent to saying that we of this era are in a more favorable position than were those of any earlier era for dealing with the problem to the end of human good. It is, of course, impossible to push consistently an attack on the problem without examining what others in other eras and lands have done at it.

Now I do not suppose any student of our day whose efforts impinge at all on the problem would hesitate a moment to think of the works of Aristotle as preëminently those of the ancient world to be examined. This it is fair to suppose because Aristotle seems now to be recognized by everybody as the founder of the science of living nature. The "father of biology" is a common short characterization of the man.

What did Aristotle do to merit this title? Surely such an inquiry as we contemplate cannot neglect that question.

BOSTON UNIVERSITY
COLLEGE OF LIBERAL ARTS
LIBRARY

Especially must we ascertain as far as possible what, if anything, he contributed to our knowledge of living beings that is and ever must be basically important to knowledge?

What is most solid in Aristotle's reputation as a ground-breaker in science rests on his researches on animal life in general and in particular on the human animal's activities as a getter and user of natural knowledge.

The familiar characterization of Aristotle as the founder of zoology may be accepted as adequate for what he did in this realm. But to characterize him as the founder of logic because of what he did at the problem of knowledge seems to me quite inadequate. As my studies have brought before me Aristotle involved in certain aspects of this problem, I have found more satisfaction in thinking of him as struggling to master the mental technique of getting knowledge of the world than in viewing him as the discoverer or inventor of formal logic.

It will be many months before the undertaking of which this is a part can be brought to completeness even as manuscript. This piece is published now in the belief that it more than any other yet completed will give such of my fellow-workers in America and Europe as have expressed some eagerness to know more about my efforts, and to get an idea of what the whole would be if completed.

Regardless of any question of the merits of my work, the utter impossibility of producing it apart from the great labors of numerous scholars in furnishing translations, notes, commentaries and so forth on the Aristotelian writings is too obvious to need saying in so many words. But it will not be amiss to remark that never before this undertaking have I felt quite so keenly the vital interdependence of diverse efforts in the world of scholarship.

While it would be impossible and quite useless to make a list of all the students of the Greek language and Greek learning without whose labors mine could not even have been begun there are three upon whom my dependence has been so immediate and personal that I must mention them. They are Provost E. A. Ross of Oriel College, Oxford University; Professor R. M. Jones, formerly of the University of California and Johns Hopkins University, lately deceased; and Professor Ivan M. Linforth, chairman of the Greek department, University of California.

But I must hasten to say that my dependence on them has not been of such character as to make them in any wise responsible for my interpretation of Aristotle as a naturalist.

I

One of the most original and far-reaching of all Aristotle's conceptions on the synthetic side of natural knowledge embodies certain of his insights into the problem of procreation and development. For one thing, he saw far more clearly than anyone before him had seen the importance of the fact that there is determinate relation between what developing bodies are and do in any given developmental stage, what they were and did in their preceding stages, and what they will be and do in succeeding stages. Fortunately, his conception of this relationship was so clear-cut that he could and did invent a word as a name for it. The word is his famous *entelecheia*. The anglicized word, entelechy, is now universally (it appears) accepted as the equivalent for this famous Greek word. In the modernized form and meaning its reputation is very bad with most working biologists.

DRIESCH'S USE OF THE WORD ENTELECHY

No professional biologist needs to be told that the bad reputation is due largely to the use made of entelechy by Professor Hans Driesch. Nothing could be further from the purpose and spirit of this enterprise of mine than a polemic over Driesch's conception. It is, however, both desir-

able and justifiable to mention the surprising (it seems to me) fact that so experienced and able a student as Driesch undoubtedly is should have adopted the word from Aristotle, and, although avowedly using it in a somewhat different sense from that in which its originator used it, should give his readers little evidence of an effort on his part to understand what Aristotle really meant by it. "The name," we read, "though well known in the metaphysical terminology of Aristotle, is not here used in the proper Aristotelian sense." (Driesch, 1914, p. 203.)

In the revised and extended edition of the *History* (1922), Driesch has given us a considerable discussion of Aristotle's theory of generation. Something of the inadequacy that still characterizes his analysis of Aristotle's use and meaning of *Entelecheia* may be indicated by calling attention to two points. One of these concerns the relation of *Entelecheia* to *energeia;* the other its relation to wholeness and purpose.

As to *energeia:* A footnote (1922, p. 12) reads: "*energeia* and *entelecheia* are nearly identical." This is all Driesch has to say on the subject. The serious defectiveness of such a view will be obvious from my discussion without further express reference to the matter.

As to wholeness and purpose: The latest (1931) we have from Driesch on this crucial aspect of the question is brief and clear. After repeating his earlier statements that his "Entelechie" is "nichtmechanische" and "nicht ganz dasselbe wie der grosse Grieche" we are told that what we positively know about "Entelechie" is: "sie bewegt sich stets im Rahmen von Ganzheit . . . . Ein ganzmachender *Kausalfaktor* ist Entelechie." (p. 416).

Here as elsewhere Driesch leaves no room for doubt that his "entelechie" has to do with the wholeness of the organism. But I find no evidence that he recognizes that the *telos* part of the word *entelecheia* has more the meaning of *holos* (wholeness) than of *proairesis* (purpose)—a point that I have dwelt on at length in this discussion. Thus it comes, it would seem, that Driesch can give a "seelenartiger Faktor, welcher *zweckmässig* handelt" (1931, p. 425) to his *entelechie* which seems to be lacking in Aristotle's word.

WHAT DID ARISTOTLE MEAN BY ENTELECHEIA?

My analysis brings out that the *entelecheia* of Aristotle is generally if not always a strictly descriptive rather than a causal term.

Owing to the Drieschian use of the word it seems best to retain the original form, *entelecheia*, in this discussion. By doing this it is fair to hope that we shall feel ourselves closer to the conception for which Aristotle invented the word, and so cleanse it, partly if not entirely, of the disrepute which rests upon the modern form of the word.

The definition of *entelecheia* given by Ross and others, namely, "actuality, complete reality," appears to be true to the make-up of the word: *enteles*, complete, in full; *echein*, have, hold.

As thus defined it seems at first thought that "the word is one which explains itself" (Wallace, 1882, Introduction, xiii). Subject a litre of water to a temperature that will change it into solid ice. The chunk of ice is then an actuality of the water's potentiality. If now you choose the word *entelecheia* as a name for the set of phenomena thus presented what more could you do to define your term than to point to the facts? And, as we shall see presently, Aristotle uses his term in essentially the simple way here indicated.

Yet we are told that "the attempt to seize and restate this thought of Aristotle

has given the history of philosophy its most valuable systems, not only such as those of Albertus Magnus and Thomas Aquinas, Leibnitz and Hegel, but also especially those of Plotinus, and Proclus among the Neoplatonists." (W. T. Harris, *Webs. Dictionary*). So we are made a bit skeptical of the view that the word "explains itself." Apparently our first thought that *entelecheia* is a simple principle needs supplementing by careful second thought.

The definition as given bears on its face evidence that the conception Aristotle aimed at by the term was closely connected in his mind with his conceptions of actuality and potentiality and of coming-to-be; in other words with his conception of genesis. But while this much about the meaning of the word is obvious from its make-up an important question is close at hand: Why did he feel the need of a new term? Why was not *energeia*, a well-established Greek word meaning actuality, good enough? True this word seems to refer very specially to action, to activity. But Aristotle makes much use of *energeia* in discussing the actual as contrasted with the potential. So if it sufficed for this meaning in some cases why not in all?

THE MEANING OF TELOS

Obviously, the *telos* portion of the word brings into it a meaning not contained in *energeia*. It consequently becomes important to ascertain as far as possible the English equivalent of the Greek *telos*. Although "end" is commonly given as its equivalent it seems that for one difference *telos* never meant end as of a stick or a road, a very common meaning of our word. Concerning its meaning the following statement is much to the point. "The Greek word *telos* has quite different associations from the English word 'end.' We may see from its use in common speech (*telos echein*, *labein*, *epitheinai*) that it implies the idea of completion. We must always think of it as the *teleiosis* of an *eidos*." (Burnet, 1900, *Intro.* xlvii, note 1.) Now if we take "to have reached *the end*, *to be finished*," the "common speech" meaning of *telos echein*; and "a particular kind" of something seen or known, as the "common speech" meaning of *eidos*, even such a general statement as the above suggests kinship of end with wholeness in the Aristotelian way of thinking.

Some of Burnet's statements in the body of his Introduction enforce the point still further.

"It is," we read, "in accordance with the whole character of this treatise (*The Nichomachean Ethics*) that Aristotle does not include in it any account of his teleological views." And again: "No animal or plant grows indefinitely: there is a point at which each is complete or full-grown." (p. xlvi.)

It is, I suppose, because this treatise on Ethics is thus characterized that a few commentators stigmatize it as "nothing but a treatise on natural history."

The indication thus noticed of the kindred of the *telos* of *entelecheia* to wholeness we find borne out by examining a wide scope of the Aristotelian writings.

Take first the following from the *De Caelo:*

> One thing, however, is clear. We cannot pass beyond body to a further kind, as we passed from length to surface, and from surface to body. For if we could, it would cease to be true that body is complete magnitude (*teleion eis megethos*). We could pass beyond it only in virtue of a defect in it; and that which is complete (*teleion*) cannot be defective, since it has being in every respect. Now bodies (*somaton*) which are classed as parts of the whole are each complete according to our formula, since each possesses every dimension. (*De Caelo* 268^{a} 31, 269^{b} 1.7 Stocks trans.)

Now although *holos* does not occur as the original of "whole" in this last sen-

tence, it does occur elsewhere in the same book of this treatise and in connections that do not seem to differ essentially from its connection here. Thus: "But since the natural movement of the whole and of its parts—of earth, for instance, as a whole (*holon*) and of a small clod—have one and the same direction, it results" etc. (*De Caelo* 270[a] 3).

Although this occurs in an argument involving the ancient false theory of the weight of bodies, the point here concerned is not, so far as I can see, affected by this fallacy.

Take now an example from the *Metaphysics*. The passage is one of the well-nigh numberless returns of Aristotle to the problem of genesis—of how things come from other things. "(3) From the compound of matter and shape, as the parts come from the whole [*ex tou holou ta mere*] and the verse from the *Iliad* and the stones from the house; the stones are to the house as part to whole, for arrangement as a house is their end, and only that which attains an end is complete" (*teleion de to echon telos*) (1023[a] 31 Ross trans.).

But the most striking instance I have found of actual synonymy (as it seems at first sight) of *telos* and *holos* is in the *Poetics*, as follows: "According to our definition, Tragedy is an imitation of an action that is complete, and whole, and of a certain magnitude." (*The Poetics* 1450[b] 25. Butcher trans.) Turning to the Greek for "complete, and whole" we find *teleias kai holes*.

The truth is Butcher's discussion of Aristotle's idea of completeness and wholeness in their application to poetry would serve very well for their application to biology. Thus we read: "The Unity of the tragic action is, again, an organic unity, an inward principle which reveals itself in the form of an outward whole. It is opposed indeed to plurality but not opposed to the idea of manifoldness and variety; for simple as it is in one sense, it admits of all the complexity of vital phenomena. The whole (*holon*) in which it is manifested is complete (*teleion*) in its parts, the parts themselves being arranged in a fixed order (*taxis*), and structurally related so that none can be removed, none transposed, without disturbing the organism." (Butcher, 1911, p. 275). "The idea of an organism evidently underlies all Aristotle's rules about unity" and Butcher quotes:

The plot must, as in a tragedy, be dramatically constructed; it must have for its subject a single action, whole and complete with a beginning, a middle, and an end. *It will thus resemble a single coherent organism*, and produce the pleasure proper to it. (p. 187; ital. as in the original.)

Is there need for more convincing evidence than is here furnished of the dominating influence of biological facts and conceptions on Aristotle's thinking even in fields which to most moderns seem utterly foreign to biology?

Butcher's discussion brings out more clearly than does the original that although "complete" and "whole" appear synonymous "at first sight" as remarked above they are not really so. "The whole in which it is manifested is complete in its parts" since these are "arranged in a fixed order" etc. In other words, whatever is complete must be whole—must all be there. But all of it may be there without its being complete. Every single item of a tragic occurrence might be mentioned but with so little verbal or sentence order as to make the whole neither intelligible nor emotionally effective. And this would correspond very well with that much practiced type of experimentation on animals in which certain parts are severed from their normal places and grafted upon other places of the same organism. For instance, a salamander with one of its legs cut off

and grafted on to its back so as to be growing there would be a whole salamander but not a complete one according to the Aristotelian nomenclature. Such a salamander would be all right as to its *holos* but not as to its *telos*. The creature would be an interesting biological specimen but teleologically it would be a monstrosity.

It seems, then, that if we take "end" as the English substitute for *telos* we must recognize that as thus used it is more akin to wholeness and completeness than to purpose in the sense of something consciously proposed and carried out by man. It was indeed used in this latter sense by the Greeks. But this seems to have been a secondary or derived meaning, employed "by philosophers" (Lexicon). The completedness of the action was even then the main idea. The *Nicomachean Ethics* of Aristotle is cited as affording examples of the use of *telos* in this sense.

Reference to Book III of this treatise, the part in which the term "purpose" of Peter's English translation is chiefly discussed, discovers what seems to me the significant fact that *telos* is not the original word for which "purpose" is substituted.

The following note on the point (Grant, 1885, Vol. II, p. 14) is illuminating:

> Having given a generic account of voluntary action, Aristotle proceeds to examine the special form of it which he calls *proairesis*. This does not mean the will as a whole (for which Aristotle has no one name), but a particular exhibition of it, namely, a conscious, determinate act of the will. "Purpose" or 'determination' is perhaps the nearest word in our language, but in fact no word exactly corresponds.

It would be entirely outside my aim, even had I the competency, to go into the endlessly discussed problem of the Will to which this Book III of the *Ethics* is devoted; or into the very technical question of the meaning of the word *proairesis*.

My sole concern is with the question of the relation between *telos* and *holos* in Aristotle's thinking with a view to understanding his reason for coining a word (*entelecheia*) which should contain *telos* as a basic element.

ENTELECHEIA AS WHOLENESS RATHER THAN AS PURPOSE

Accordingly if we view the result here reached by our examination of *telos*, in the light of what has been seen throughout this essay about "our usual method of research," the method, that is, of analyzing wholes into their parts and then learning as much as possible about the parts, are we not obliged to conclude that Aristotle's conception of *entelecheia* had much more to do with his conception of complete wholeness than with purpose in the sense most usual with us? To illustrate, when we find Aristotle saying (in translation) that the "purpose" of the lips is to protect the teeth as well as to serve the higher office of speech (*De Partibus* 659^{b} 30 Ogle trans.) we should understand the chief meaning to be not that nature planned, in the human sense of planning, lips to serve thus; but that by nature they actually do function in this way.

Especially would it seem that with purpose in the sense against which recent biology has had to train its heaviest guns, Aristotle was by no means greatly concerned, either with his word *entelecheia* or in his thinking about natural phenomena generally.

The teleology for which Aristotle is roundly condemned by many present-day biologists he was not at all or very slightly guilty of. On the other hand those who condemn the teleology which he did hold, that of completed wholeness as essential to the adequate interpretation of any phenomena of nature whatever, are in so far not only failing, themselves, in reaching such interpretation, but are tacitly denying the possibility of it.

What Aristotle is justly chargeable with is that, having become impressed with the idea of adaptation in living beings, he worked the idea altogether too hard. Thus the idea later known as the "balance of parts" of organisms as dependent on the distribution of the supply of growth material available to the individual, he pushed to absurd lengths at times. The explanation of man's taillessness on the supposition that his buttocks have monopolized the material available to this portion of the body (*De Partibus* 689^b 20) is an example of much of his reasoning of this sort. How far he might be justly excused on the ground of the very meager knowledge possessed by him of the physiology and biochemistry of growth is an interesting question.

Taking into account, then, the constancy with which Aristotle kept individual man before him as an example of a complete whole; and into account also his never-failing recognition that a man like all other animals is a product of natural genesis, we might reasonably expect to find the term *entelecheia* given an especially large place in the *Generation of Animals*. As a matter of fact, however, it does not occur extensively in this treatise—nor in the other most definitely zoological treatises. It appears not to occur at all in the *History of Animals* and only a few times in the *Parts of Animals*. The *Physics*, the *Metaphysics* and the *De Anima* are the works in which it is most used. But it is also used in the *Meteorology* and the *De Caelo*.

It may be that this distribution of the word is partly responsible for the view of Werner Jaeger that "Die (*entelecheia*) hat einen logisch-ontologischen, doch keinen biologischen Sinn." (Jaeger, 1923, p. 410.) But a fairly comprehensive study of Aristotle's use of the word discovers that, while the affirmative part of Jaeger's statement is true, the negative part (the part denying biological meaning to the word) is not true if "keinen biologischen Sinn" would exclude application of the word to phenomena of living beings.

PHYSICAL APPLICATIONS OF ENTELECHEIA

Proceeding now to such a study we first show that Aristotle uses the term extensively in connection with purely physical phenomena (physical in the modern sense). Then we go on and find him applying it to biological phenomena. Following this we tackle the hard task of trying to understand what, exactly, he meant by the term. And finally we inquire not only how wide an application he actually gave it but how much farther he might have applied it consistently with his basic idea had his scientific knowledge been more comprehensive.

We first notice a use of the term in the *Meteorology*, as follows:

> We must now describe the forms taken by the passive qualities, the moist and the dry. The elements of bodies, that is, the passive ones, are the moist and dry; the bodies themselves are compounded of them and whichever predominates determines the nature of the body; thus some bodies partake more of the dry, others of the moist. All the forms to be described will exist either actually [*entelecheia*], or potentially and in their opposite; for instance, there is actual melting and on the other hand that which admits of being melted. (*Meteorologica* 381^b 22–28 E.W. Webster trans.)

Obvious enough, is it not, that "melting" and "melted" of the quotation would apply to ice as well as to any other solid that "admits of being melted?" The use of *entelecheia* in this connection seems especially significant from the fact that, despite the practical non-existence of the science of thermodynamics in Aristotle's time, in the whole round of physical phenomena which he treated there is hardly a subject in which his innate devotion to objective reality stands out more strikingly than in his discussions of

this and kindred subjects in the book, (the fourth), of the *Meteorology* in which this discussion occurs.

Although the term occurs but once, so far as I know, in *De Caelo*, its use here is specially interesting:

> Now whenever air comes into being out of water, light out of heavy, it goes to the upper place. It is forthwith light; becoming is at an end, and in that place it has being. Obviously, then, it is a potentiality, which, in its passage to actuality, comes into that place and quantity and quality which belong to its actuality. (311ª 1–5 Stocks trans.)

For the point in hand we are concerned with nothing except the fact that *entelecheia* ("actuality" of the translation) is used in connection with the supposed transformation of one purely physical body, water, into another purely physical body, air. That no such transformation occurs, and that Aristotle's main discussion here, namely about heavy and light, is pitifully wrong, should not obscure the point we are after. Both water and air were objective realities in ancient Greece just as they are in modern America. So wrong reasoning about their relation to each other does not alter either the fact of their existence, or the basic principles on which the reasoning rests.

Turning now to the *Physics* for instances of the application of *entelecheia*, we first notice Aristotle dealing with this same case of water and air, only from a somewhat different angle: "And this is how air is related to water; for air is the form and water the material, the air in a sense being the actualizing [*entelecheia*] of water since the water is potentially air, as indeed air is potentially water, but in a different way." (213ª 5–10, Wicksteed trans.) The problem of the relation of the matter of a thing to its form is, of course, the main point under discussion.

Another sharply physical application of the term is to the relation between hot and cold: "And since in certain cases the same thing may have both an actuality [*entelecheia*] and a potentiality [*dynamis*] (not indeed at the same time or not in the same respect, but potentially hot, for instance, and actually [*entelecheia*] cold), it follows that many things act on, and are acted on by, each other: for anything will be at once capable of acting and of being acted upon." (*Physics* 201ª 20.)

One may well question whether *entelecheia* has any meaning here that would not be expressed by *energeia*. Stimulated by this question, I have tried to answer it by a little excursion into the translators' field. Clearly, the English wording "but potentially hot . . . . and actually cold" is crucial for the point. The original is: *all hoion thermon men dynamei psychron de entelecheia*. While the Wicksteed rendering is quite permissible, Professor Linforth assures me, he also assures me that the following is quite as permissible: "But potentially hot . . . . as well as actually cold." Surely this wording does not differ fundamentally from that of the published text.

But, going somewhat more on the basis of my own than the other wording, I offer the following as what seems to be the meaning of the whole passage: We are now observing (experiencing) a particular body of water and the experience we have of it we name cold. But since on previous observations of the same water, our experience of it was different and of a sort we named hot, we must recognize that even now it has the ability (potentiality) to be hot. This double attribute of the water we may, with Aristotle, name *entelecheia*.

Immediately preceding the instance thus noticed we have the following enormously broadened application of the concept: "Building material is actualizing [*entelecheia*] the potentialities in virtue of which we call it 'building material' when it is in the act of being built into a structure, and this act is the process or 'movement' of 'building'; and so too with other processes—learning, healing, rolling, jumping, maturing, aging." (201ª 13–20.)

We now notice an instance of the application of *entelecheia* to a phenomenon of the physical realm (physical in the modern

sense) that is especially significant from its place of occurrence. The phenomenon is light and the place of occurrence is the *De Anima*. Aristotle's erroneous theory of light assumed the existence of an entity which he called the diaphanous, this entity being somewhat similar to "air, water and many solid bodies." To this entity light is due as a "sort of colour." On this basis he could say: "Of this substance light is the activity [*energeia*]—the activity of what is transparent so far forth as it has in it the determinate power of becoming transparent; where this power is present, there is also the potentiality of the contrary, viz. darkness. Light is as it were the proper colour of what is transparent, and exists whenever the potentially transparent is excited to actuality [*entelecheia*] by the influence of fire or something resembling 'the uppermost body;' for fire too contains something which is one and the same with the substance in question." (*De Anima* 418^{b} 8–13 Smith trans.)

It would seem that the rendering of *entelecheia* here by "complete reality" would bring out more sharply the distinction between *energeia* of the preceding sentence and the *entelecheia* of this sentence, than does the "actuality" of the translation as quoted. The "transparent *qua* transparent" of the first sentence appears to mean that light merely as the energy of the diaphanous is something less than what it is after having been acted upon by the celestial body (i.e. the aether) which in one of its attributes is the same as fire. But however all this may be the main point for us is that Aristotle here gives us especially convincing evidence that his concept, *entelecheia*, was applicable in the inanimate as well as in the animate portion of nature. Wallace's translation of *entelecheia diaphanes* by "realized into full pellucidity" seems close to the original meaning.

Is there need of further effort by either illustration or argument to show that Aristotle's conception of *entelecheia* applied to phenomena of becoming in inanimate nature and in the broad realm of man's art? Almost unlimited evidence to the same effect could be given. But economy of time, space and labor justify us, we hope, in passing on now to another phase of the subject.

BIOLOGICAL APPLICATIONS OF ENTELECHEIA

Reference was made above to the fact that the word *entelecheia* does not occur often in any of the zoological treatises. How can this have happened if the concept held as important a place in Aristotle's synthetic thinking about living nature as we conclude that it did hold?

The evidence available seems to me adequate for a satisfactory answer to the question.

Notice has already been taken of the fact that living bodies (individual men by no means excepted) came within the domain of "physics" for Aristotle as indubitably as did rocks or rainbows or rivers or any other natural objects. Hence what we actually find is that although the term *entelecheia* is used more frequently in the *Physics* than in the zoological treatises, even here it often has reference to living beings. Take an instance. Following a general statement about bodies acting on other bodies with the result that in some cases the acting body contributes some of its own characteristics to the body acted on, we read: "Thus the man in actuality [*entelecheia*] produces the actual out of something which has the potentiality [*dynamei*] of becoming man." (*Physics* 202^{a} 10 Wicksteed and Cornford trans.) More of this dealing with man in the *Physics* will be noticed in our attempt to understand the meaning of *entelecheia*.

We now proceed to notice the application of the term to strictly biological phenomena. Concerning the principle by which "flesh is flesh and bone is bone" we read: "What makes them is the movement set up by the male parent, who is in actuality [*entelecheia*] what that out of which the

offspring is made is in potentiality." (*De Generatione Animalium* 734[b] 34–36 Platt trans.)

Further in much the same vein: "Moreover, the seed is potentially that which will spring from it, and the relation of potentiality to actuality [*entelecheia*] we know." (*De Partibus Animalium* 642[a] 1 Ogle trans.) This occurs in a rather general discussion of the germ or seed of organisms, animals and plants.

That Aristotle used his famous word in discussions of the production, or genesis, or coming-to-be of all sorts of things, natural and artificial, may now be considered as sufficiently illustrated. So we turn to the more difficult task of learning as far as we can what exactly he meant by it. This discussion may begin with a reference to Jaeger's view previously noticed that *entelecheia* is a logical and ontological conception.

ONTOLOGY AND ONTOGENY

We notice first of all that the basic part of the philosophically hallowed term *ontology* is *ont*, that which exists. This with its plural *onta*, all sorts of existing things, would surely be a highly useful term to a Greek who, like Aristotle, was devoted to Particulars as well as to the Universal. As one illustration: "in a manner the soul is all existent things [*psyche ta onta*]" (*De Anima* 431[b] 21 Hicks trans.)

In the second place we note that embryology in particular has adopted the proposal of Ernst Haeckel to use this same word as foundational in a term, *ontogenesis*, for the development of the individual organism as contrasted with the term, phylogenesis, for the development (evolution) of the tribe, or race of organisms.

When the embryologist speaks of the ontogeny of the chick or frog he refers to a very definite thing, namely the development, the coming-to-be, of an individual fowl or frog. Consistently with this the general biologist might speak of the ontology of the chick or frog. That is to say, he could consistently apply this term for the general treatment in knowledge, as of the anatomy and physiology, for instance, of chick or frog. As a matter of fact, though, ontology is never, so far as I know, used thus in biology. This may be because the term was appropriated by metaphysics long before the existence of modern biology. By this is meant that professional "thinkers" (in contrast with those who observe-and-think) long ago developed the "ontological argument," so named, to prove the existence of a Being, (God), supposed to be utterly distinct from and superior to, any of the beings known or knowable through sensory experience. The kernel of this mediaeval theory was the belief that our knowledge of objects the obtaining of which is wholly dependent, finally, on sense experience can yet be used to get knowledge of other objects about which we can learn nothing whatever by sense experience.

The only reason for alluding to this famous doctrine is as an aid to bringing out the point that whatever may have been the views of Aristotle or any other Greek concerning the existence of a Being or Beings of the kind mentioned, certain it is that Aristotle's whole teaching concerning the genesis of living beings is concerned exclusively with individual organisms. Biologically his teaching was as strictly ontogenic as is that of the most up-to-date geneticist. My view of this matter agrees with that of E. S. Russell (1930, p. 13) that Aristotle's "whole philosophy is indeed a biological one."

ENTELECHEIA AND GENESIS

What we have to do now is to recognize that Aristotle's concept of *entelecheia* was

accordant with his general teaching about the nature of objects and their coming into existence.

Although, as we have seen, Aristotle did not by any means apply the conception to living beings alone—in fact he used the term somewhat less in the biological treatises than in some of those not nominally biological—yet it is in certain discussions that are really biological though occurring in non-biological works that the nature of his conception comes out most clearly.

We will first examine one of these discussions from the *Physics*.

In an inquiry concerning what is meant by the nature of objects of various kinds we read:

> And as, in the case of art, we should not allow that what was only potentially a bedstead and had not yet received the form of bed had in it as yet any art-formed element, or could be called 'art,' so in the case of natural products; what is potentially flesh or bone has not yet the 'nature' of flesh until it actually assumes the form indicated by the definition that constitutes it the thing in question, nor is this potential flesh or bone as yet a product of nature. These considerations would lead us to revise our definition of nature as follows: Nature is the distinctive form or quality of such things as have within themselves a principle of motion, such form or characteristic property not being separable from the things themselves, save conceptually. (The *compositum*—a man, for example—which material and form combine to constitute, is not itself a 'nature', but a thing that comes to be by natural process.) And this view of where to look for the nature of things is preferable to that which finds it in the material; for when we speak of the thing into the nature of which we are inquiring, we mean by its name an actuality [*entelecheia*] not a potentiality merely. (*Physics* 193[a] 35–193[b] 5 Wicksteed trans.)

The fact that the reference to "a man" is quite incidental to the main argument here is particularly significant for our view concerning Aristotle's meaning of *entelecheia*. This is so from its being another illustration of the perpetual availability, so to speak, of "a man" in his mind for illustrating natural bodies in many of their aspects. Still more distinctly to the same effect he continues: "Again men propagate men, but bedsteads do not propagate bedsteads; and that is why they say that the natural factor in a bedstead is not its shape but the wood—to wit, because wood and not bedstead would come up if it germinated. If, then, it is this incapacity of reproduction that makes a thing art and not nature, then the form of natural things will be their nature, as in the parallel case of art. . . . . .

"Again, *na-ture* is etymologically equivalent to *gene-sis* and (in Greek) is actually used as a synonym for it; nature, then, *qua* genesis proclaims itself as the path to nature *qua* goal." (193[b] 12.)

The original of the first line of the last quotation is: *physis e legomene os genesis*. And in the statement "nature, then, *qua* genesis" *physis* is, of course, the original of "nature." In the light of such passages we see the deplorable perversion of Greek, especially of Aristotelian, thought that is involved in the modern effort to make the sharpest kind of a distinction between physics and biology (unless biology be taken in a strictly atomistic sense); and then to berate Aristotle for his failure as physicist.

Only as we recognize the *De Generatione* as a treatise on a division of physics and likewise on a division of natural history, do we get a clear comprehension of what science was to Aristotle.

This example of Aristotle's familiar comparison of "works of nature" with "works of art" exhibits particularly well some of the crucial points he obviously wanted to make by the comparison. One of these is that of the relation between the concepts of potentiality and actuality. Another is the similarity but yet the difference between natural and artificial causation and production. On this account it is worth while to reflect a bit farther on the example.

For this is a good chance to call attention to the fact that Aristotle's comparison of the products of nature with those

of art is close of kin to the comparison in modern biology of organisms with machines. It should be noted that while Aristotle made this comparison, he did not fail to point out the difference between the two. He never proposed an explanatory theory of organisms that would make artificial products of them—as is really the case with the modern mechanistic theory of life. A machine is of course a product of the mechanic arts.

Taking up the bearing of the example on the concepts of potentiality and actuality we note that the material constituting both bedstead and bone must be capable of constituting them. That is to say, adopting the terminology which characterizes the Aristotelian writings almost as much as do the letters of the alphabet, the materials of bedsteads and bones are potentially but not actually, these things. They are actually these only when the form distinctive of them has been impressed upon the materials by some agency which the materials just as such (materials *qua* materials) show no signs of. And when a thing has become a bedstead or a bone in actuality, through the proper combination of its matter and its form, we are confronted with the obvious but difficultly answered question as to what agencies (causes) are responsible for the coming-to-be of the actual things—bedstead and bone. Do the agency or agencies reside wholly within the materials? Or wholly outside the materials? Or partly inside and partly outside the materials?

For the bedstead there is no difficulty as to part of the answer. The wood has no active bedstead-producing capacity at all. The agencies of the coming-to-be here are clearly the designer and manufacturer—though their tools must not be wholly overlooked. The wood (the material) is entirely passive in the maker's hands. Nevertheless, passive though the material is, it yet does have a certain bedstead potentiality. It can be shaped into a real bedstead—which could hardly be the case with butter, let us say; or certainly not with butter-milk, or with milk in its typical state.

But when it comes to bone, the question of the agency of its coming-to-be is much more difficult.

However, the production of a bone *by some agency* is as certain an occurrence in a man's development as is the production of a bedstead by a manufacturer.

EPIGENESIS

We have here an instance of Aristotle's assumption of the truth of what modern embryology knows as epigenesis (genesis part-by-part). And this assumption rests securely on his own researches into the embryogeny of the chick and other animals. So familiar was he with the fact that the parts (organs, tissues, etc.) come into existence one after another as the embryo increases in size that seemingly he never even thought of the surprising notion of "preformation" which many centuries later came into vogue among students of development. For Aristotle and the other Greek naturalists the only alternative to the one-after-another theory was the possibility that the parts might all come-to-be simultaneously. The question was as to whether "all the parts, as heart, lung, liver, eye and all the rest come into being together or in succession, as is said in the verse ascribed to Orpheus, for there he says that an animal comes into being in the same way as the knitting of a net." (*De Generatione* 734[a] 17.)

But the theory of simultaneity is found to be entirely without foundation once the light of observation and sound logic are turned upon it. "That it is not the fact is plain even to the senses, for some of the parts are clearly visible as already existing

in the embryo while others are not." (734[a] 20). Then in what immediately follows we notice a bit of good morphological reasoning: "that it is not because of their being too small that they are not visible is clear, for the lung is of greater size than the heart, and yet appears later than the heart in the original development." In the development of a full sized adult man (for instance) from germ to adult the parts are not only produced one after another, but when produced they remain, typically, to the end of the individual life, each having its special function that is characteristic and definitive of the man. The completed man consists of a great number of parts which have successively come-to-be, each having its own characteristic matter-and-form and likewise its own activities. But these many parts must be, in order really to constitute a man, not an assemblage but a unified whole. They must be a "complete reality." The potentialities of the germ are, at the end of the man's life, if all has gone well, fully realized as to some of its potentialities, especially its physical potentialities. Thus there stands before us a highly complex single (particular) example of a kind of entity for which our common speech has no name. In order therefore that our conversation may be really intelligible when we treat of this entity we must invent a name for it. But Aristotle has forestalled moderns here as in numerous other cases. *Entelecheia* is the name he invented; and if by keeping its original Greek form we can rescue it from the perversions it has suffered at the hands of later men (e.g. Leibniz and Driesch) there is no reason why we should not adopt it and avoid the necessity of inventing another name. So are we not now prepared to clear our minds of vagueness as to what the "complete reality" of a man is as a conception to which Aristotle gave this name? And individual man thus conceived would be a completed whole of material and spiritual attributes of the species *Homo sapiens*, this whole including the entire life career from fertilized germ to the last day of normal adult life.

That all human beings possess a far greater number and effectiveness of potentialities (as to language and manual skills for instance) than can possibly be brought to practical realization, while it very greatly complicates the conception still leaves it clear in principle.

On the material side there is of course the whole equipment of flesh and bone (adhering to the usual Aristotelian terminology of general anatomical reference); and also the whole round of movements, as of nutrition and generation (again adhering to the Aristotelian language, now of general physiological reference). Without essential departure from the truth we may say that the zoological treatises represent the Aristotelian effort to analyze this aspect of the *entelecheia* of the human and all other animal species. The inference seems to me hardly escapable that Aristotle's great interest and industry in the dissection of animals was a manifestation of his recognition of analysis as fundamental to science.

On the spiritual side the vast concourse of human phenomena proper of which language and literature, art in the broadest sense of manual construction, inter-individual conduct, family and social organization and so on until nothing human whatever is omitted. Again with but little violence to truth we may say that the treatises on *Logic*, *Rhetoric*, and *Poetry*; and on *Politics* and *Ethics* are the Aristotelian effort to analyze the *entelecheia* of man on the spiritual side of his nature.

ENTELECHEIA AS COMPLETE REALITY

Really then what have we in this term as applied to man but a name for our own

conception of a man *whole*? In other words the term *entelecheia* seems available as a name for the general conception we have been working toward in this entire book. Justifiable indeed therefore is Will Durant's characterization of *Entelecheia* as "one of those magnificent Aristotelian terms which gather up into themselves a whole philosophy." (Durant, 1926, p. 81 note). More specifically definitive of the term is Windelband's: "This self-realisation of the essence in the phenomena, Aristotle calls *entelechy* [*entelecheia*]" (Windelband, 1905, p. 140). What is the essence of the phenomenon we call a man, if it is not a man himself who goes as far as possible toward completely realizing himself? And who or what can realise, actualize, a man but a man himself?

As thus presented there is an obviousness about the idea that makes it look at first sight simpler than it really is.

In following the Aristotelian way of keeping man at the front in discussing this part of the problem of *entelecheia*, we have had the advantage of familiarity. Each one of us certainly has more intimate knowledge of himself than he has of anybody else—or for that matter of any other creature or thing whatever. But at the same time we have had the disadvantage of one of the most complicated of all the applications of the conception. Seeking an offset for this disadvantage let us revert to what we have learned about its application in much simpler cases. For instance we have learned that the idea applies to each and every definable part of a man. The femur or liver or stomach or brain, for example, each has its own *entelecheia*. Each and every organ is a sort of thing-in-itself. Embryology is now advanced far enough to make us certain that each of these parts has its initial, or germinal stage (variously called, especially if the stage is clear cut, the fundament, or *Anlage*), this being followed by a whole series of stages till the full-fledged, functionally mature organ is present, i.e. has come-to-be.

From such passages and reflections as are now before us is there any mistaking what Aristotle was aiming at? In using individual man to show what he understands by the nature of a thing he takes him (the man) in his adult or finished state (goal), this being his most definitive form; recognizes this state as having been reached along the "path" thereto (*ontogeny*); takes further the germ and the materials (the potentialities) that have gone to the making of the flesh, bones and all else occurring in the various ontogenic stages and the final stage with the intrinsic "principle of motion" (growth and differentiation) appertaining to the whole process; and finally he takes the entirety, the "complete reality"—germ, material, motion, form and whatever, if anything more, there may be that is "not separable from the things themselves"—and invents as a name for it the word *entelecheia*.

ENTELECHEIA AND HEREDITY

Now it may seem to some readers that there is not enough in the foregoing presentation to fully justify the inclusion (as my summary does include) of the germ and all the ontogenic stages, structural and functional, in the "complete reality" of a man. Consequently this aspect of the matter had better be supplemented. This can be done by passages from the formal treatment of the reproduction and development of man in the *De Generatione*. Requisite passages occur in the elaborate discussion of Aristotle's well-known theory, distressingly false as to fact but astonishingly correct as to much of the reasoning, that the semen of the male is the material by which alone heredity is accomplished.

The main aim of the discussion is to show that a particular organism (erroneously a male) in its entirety produces the semen which in turn gives rise to the new organism in its entirety. We have here one of the most original, most profound, and most inescapable of all Aristotle's examples of what "our usual method of research" can accomplish. For it is doubtful if there is any other instance in his writings of more adequate and searching combination of observation and reason, and of objective analysis and synthesis, than we have here.

The immediate goad to his effort was the attempt by Hippocrates to interpret the reproduction and ontogeny of living beings on the basis of the atomistic theory of Democritus and his followers. Such an attempt Aristotle naturally saw was irreconcilable with his conception of a whole-and-its-parts. We must inquire, he says, "what those animals which emit semen contribute by means of it to generation, and generally what is the nature of semen." (721^b 1–5).

We omit from these quotations the passages concerning the female contribution (the catamenia) in propagation. This is permissible from the fact that the sad error into which Aristotle fell here does not affect the facts and the reasoning as to the origin, nature and action of germinal material proper.

And he further tells us that we must ask "whether it [the semen] comes from the whole of the body or not from the whole." (721^b 10). It was just here that he faced the Hippocratian theory and all similar theories down to our own time. This theory, of which Darwin's Pangenesis is the most famous modern example, was that the semen (germinal material) comes "from the whole body." That is to say, the theory was that every part of the body produces or is represented by, one or more minute particles and that it is by means of these that a new organism resembling the parent is produced.

Aristotle was able to demonstrate that such a theory of the origin of the semen cannot possibly be true. The observations and reasonings involved in the demonstration we need not follow in detail, since they are elaborate and no modern biologist gives any credence to the theory in either its Hippocratian or its Darwinian form.

But then came the exceedingly hard question, What can be the origin and the nature of the semen? For surely it does somehow bring to pass the development of an individual resembling its parent more or less closely. Aristotle's treatment of this fundamental problem is specially remarkable from the way the principles of reasoning are applied to such meager observational data as he possessed. To quote it in full would be a serious matter; and, for reasons which we shall see in a moment, our present aims do not require this. However, no reader bent on forming a true estimate of Aristotle's merits as a thinker on the phenomena of living beings will fail to read the entire discussion.

Attention may be called to the chapter "Aristotle's 'De Generatione Animalium'" (Russell, 1930, pp. 11–24). Nowhere else, so far as I know, is there so adequate and helpful an exposition of this part of Aristotle's teaching on generation.

The reason why our present aims permit us to forego a detailed examination of Aristotle's treatment is this: After all we have learned (in portions of the general work not included in this article) about his insistence on the importance of potentiality and actuality, and of matter and form, the guess should be close at hand that he would see that the problems of reproduction and ontogeny come largely under this general head. It will therefore suffice to quote a few sentences to show

how clearly he saw this. The phenomena of chemical transformation (as we now know it) naturally played an essential part in the argument—as we have found it doing (in portions of the general work not included in this article) in various other of his discussions.

We will notice first his way of answering the question of where or how the semen originates. After mentioning that all the parts, both tissues and organs, of a full-grown organism have a composition of one kind or another, he makes the point that if the semen contained particles derived from all these they, the particles, would have to be composed also as well as be just particles: "If really flesh and bones are composed of fire and the like elements, the semen would come rather from the elements than anything else, for how can it come from their composition? Yet without this composition there would be no resemblance. If again something creates this composition later, it would be *this* that would be the cause of the resemblance, not the coming of the semen from every part of the body." (722 $^{a\&b}$).

Yet Aristotle well knew from his own investigations, that there is no such original composition of tissues and organs in the germ. These come into being one after another as the embryo increases in size and complexity. It is now well known, as previously mentioned, that Aristotle was an out-and-out epigenesist (in modern parlance) two thousand years before that idea was fully established as the true mode of ontogeny.

And the principle, he pointed out, of semen formation is the same that operates in the formation of various parts of an organism from other parts: "It is clear, then, that that which comes from any part, [i.e. part of the embryo as to corresponding part of the parent], as blood from blood or flesh from flesh, will not be identical with that part. But if it is something different from which the blood of the offspring comes, the coming of the semen from all the parts will not be the cause of the resemblance, as is held by the supporters of this theory. For if blood is formed from something which is not blood, it is enough that the semen come from one part only, for why should not all the other parts of the offspring as well as blood be formed from one part of the parent?" (722^{b} –725^{a}).

From this much on the question of how semen is produced we pass to the question of what it in turn produces.

"But how," we read, "is each part formed? We must answer this by starting in the first instance from the principle that, in all products of Nature or art, a thing is made by something actually existing out of that which is potentially such as the finished product. Now semen is of such a nature, and has in it such a principle of motion, that when the motion ceases each of the parts comes into being, and that as a part having life or soul" (734^{b} 20).

Platt, the translator, raises the question whether the word, *pauomenes* (the reading of the original), which it seems must be rendered "ceases," is sound text. He suggests that *luomenes*, meaning "when the motion is resolving," would be in better accord with other passages dealing with hereditary transmission. This would certainly fit better with what we now know about fertilization, cell division, and all the succeeding ontogenic phenomena.

The next quotation is selected to illustrate that while Aristotle recognized the rôle of environmental factors in ontogenesis he was sure that germinal potentialities were the primary causal factors of hereditary transmission: "While, then, we may allow that hardness and softness, stickiness and brittleness, and whatever other qualities are found in the parts that have life and soul, may be caused by mere heat and cold, yet, when we

come to the principle in virtue of which flesh is flesh and bone is bone, that is no longer so; what makes them is the movement set up by the male parent who is in actuality what that out of which the offspring is made is in potentiality." (734^{b} 30–35).

Aristotle's recognition that temperature (heat and cold) is an external factor in development is of course a point to be noted. But more important is what follows: "The principle" that makes flesh flesh and bone bone is the process started by the male parent who is actually what the offspring is potentially. The Greek word, Platt points out, here rendered "principle" is *logos*. Now everybody knows something about the difficulty there is in translating this old word into the English language. But there appears to be general agreement that whatever else may be contained in it, it surely has a connotation of "word," or "saying" that is rationally grounded. It would seem that "rational principle" would be the briefest possible rendering of the word that Aristotle used. But note these dictionary meanings of *logos*: "I. the word by which the inward thought or reason is expressed: II. the inward thought or reason itself." See what, then, on the basis of these meanings of *logos*, we are told it is that makes "flesh flesh and bone bone." It is the movement set up in generation by means of the semen of the male parent, as all this stands in one's "inward thought or reason." In other words that which makes flesh flesh and bone bone has a twofold nature. It is an objective reality of a sort (specifically an individual human being) and it is what that human being is in the observer's and speaker's inward thought, namely a male parent begetting an offspring through the agency of the semen which he produces.

Now reflect on Jaeger's definition of *entelecheia* in the light of our examination of Aristotle's application and meaning of it. Recall that according to the Jaeger definition the term is logical and ontological. Has not our examination found it to be both of these? The *logos* (rational principle) involved in our knowledge of a parent's part in making flesh flesh and bone bone, recognizes the logical element or factor in the *entelecheia* of the parent. Also the basic kindred between ontology and ontogeny, clearly seen (though not directly specified) by Aristotle, recognizes the ontological element in that *entelecheia*.

But recall further that the definition in question denies that *entelecheia* is biological. Our examination finds, on the contrary, it to be as fundamentally biological as it is logical and ontological. Indeed what we find is that its ontological nature is directly dependent on its biological nature. The *ontos* (the being) for which Aristotle saw the need of a word for expressing it in one of its most important aspects he also saw must be a word which the Greek language did not contain. And the language lacked such a word, he saw, because nobody before him had seen clearly that *the ontos which knows and thinks is the very same that is begotten, develops, and in turn begets another of its kind.*

THE GERMPLASM THEORY

Now surely no present-day biologist would fail to recognize that in tackling the problem of the origin and nature of semen (germinal substances) and its rôle in heredity, Aristotle was plunging into one of the most complex and difficult of all the problems of living nature. Furthermore such a biologist would hardly fail to recognize that while he was able to dispose in a masterly fashion of the erroneous theory of his predecessors concerning the origin of the germinal substance from every part of the body, and was also able to demonstrate the epigenetic mode of ontog-

eny, he nevertheless failed to arrive at the theory concerning the origin and nature of the germinal substance which is today very widely held. That is to say the modern biologist would not fail to remark that Aristotle's conclusion, that although the germinal substance is not produced as particles from all parts of the body, yet it is produced in such a way by the parent that it represents in potentiality all the parts, is contrary to the germplasm theory of modern genetics. For this theory holds, as is well known, that what is actually transferred from parent to offspring in reproduction is true germinal substance, or germplasm only, this being entirely independent of the body substance, or somatic plasm so far as its production is concerned. Germplasm can produce somatic plasm and a body but somatic plasm and a body cannot produce germplasm. In a word the parent in actuality (as Aristotle would say) does not after all really produce his own offspring as in ordinary experience he seems to and as according to Aristotle's teaching he actually does.

Now since few phenomena of living nature are more vital to human welfare than those we are here dealing with; and since further the sense data aspect of the problems involved was definitely opened up by Aristotle and has latterly developed into enormous complexity; and since finally, Aristotle as both logician and biologist instead of biologist only was in position to deal with the logical aspect as few modern biologists are prepared to deal with it, the general character of the task we have undertaken seems clear. We cannot, of course, ignore the sense data aspect. But our effort just here must be with the logical-epistemological aspect of ontogenesis, our concern being with the aspect to which Aristotle gave quite as much attention as he did to the sense data aspect, but which modern biologists have neglected almost entirely.

I trust my use of the term "epistemology" will not prejudice my case. Its convenience as compared with such phrases as "theory of knowledge," "knowledge processes," "the getting-and-using of knowledge," etc. (phrases which better express my meaning) is obvious from its usableness in the adjective form.

So elaborately and so frequently is the sense data aspect presented in our day that we shall be justified in treating it very briefly.

It is important to be clear as to what, exactly, the sense data are in the problems of heredity and the agencies by which the processes of heredity operate. First and foremost these data are the observed characters of individual organisms, chiefly in their adult state. The number, variety, and complexity of these characters are so obvious that they need be referred to only in the most off-hand way. In man, for instance, mentioning only the most obvious, of external characters there are his upright posture, form and size of his legs-and-feet, arms-and-hands, head, and hair; the color of his skin, hair and eyes; his voice and general activities as indices of his mentality; and so on and on.

As to the agencies by which heredity operates there is the vast body of observational knowledge of both the male and the female generative products—spermatozoa and ova. The portion of this knowledge which figures most in present-day theories is, of course, the chromatin of the nuclei of the germ cells. This material, disposed in granules and rather definite bodies, the chromosomes, is really the sole observational basis of these theories.

In the interest of clarity as to what are and what are not sense data in the problems it should be said that the two terms, *germplasm* and *genes*, though holding crucial places in all discussions of current genetic

theory, do not denote any objects as sense data. They are not known by direct observation. They are deductions from observations on the organisms themselves and on the chromosomes of their germ cells. Striking indeed are the deductive grounds for the concept of germplasm. But all the more because of this strikingness is it important to keep firmly in mind exactly what sense data the reasoning depends upon.

Should the very recent reports (e.g. Belling, 1931) of the observation of great numbers of exceedingly minute bodies in the chromosomes of certain plants be verified and proved to hold for all organisms, and should these bodies be proved by observation to be fundamentally connected with heredity, the statement just made that genes are known only deductively would, of course, not be true.

The question that specially concerns this inquiry is not that of the *existence* of genes and germplasm but of the supposed *isolation*, or independence, of germinal material from the body and the somatic material. The sharpness of the isolation finds expression in almost every biological textbook, to say nothing of technical treatises on genetics, of the present era. The following example presents the theory in a considerably less radical form than do many presentations: "It is customary, therefore, to draw a more or less sharp distinction between soma and germ—to consider the soma the individual which harbors, as it were, the germ destined to continue the race. This theory of *germinal continuity*, which is chiefly associated with the name of Weismann, recognizes that the germ contains living material which has come down in unbroken continuity ever since the origin of life and which is destined to persist in some form as long as life itself." (Woodruff, 1923, p. 216.)

The tendency of the theory to minimize the rôle of parents in the begetting of their children is set forth quite startlingly by some writers. A comparatively moderate instance of the tendency is this: "In accordance with this view the offspring can hardly be said to inherit its characters from the parent at all, but both derive them from a common source, the continuous stream of germplasm." (Dendy, 1922, p. 167.)

THE THEORY OF THE GENE

The theory of "The Gene," which is playing an enormous part in contemporary genetics, differs in a number of ways from other particleist theories (those of biophores, pangens, determinants, etc.). Nevertheless it is at one with these in purpose and spirit. It aims to express or explain what can be learned by observation, both common and technical, about organisms, in the terms of, or on the basis of, particles always so minute as to be beyond the limits of direct observation. The chief difference between genes and other particles of similar theories depends more on the methods of experimentation and reasoning by which they have been deduced, than on their real nature. Here is a typical glossary definition: "*Gene* A factor or element in the chromosomes of the germ cells which conditions a character of an organism." (Woodruff, p. 439.)

The use of the term "factor" as an alternative for element deserves notice. "Factor," reaching back as it does to *facere*, to do, connotes action more obviously than does "element," this having no necessary active connotation at all. Because of this meaning of factor some of the more critical geneticists are inclined to discard the term gene altogether and use factor in its stead. But so strong a desire for concrete reality have natural scientists generally that less critical geneticists exert much speculative effort to corpuscularize the gene.

It is important to notice that this or any other definition of gene or of ultimate biological particles under whatever name, says nothing about any characters of their

very own. Such entities are always defined in terms of what they are conceived to do relative to characters of other bodies well known observationally. The concept of any or all such bodies is in flat defiance of the logical principle of identity, one of the most basic principles of the Aristotelian or any other dependable logic of observational knowledge. But consistently with our declared purpose we must forego the task of critically examining here the use made of sense data in support of either the germplasm theory or the theory of the gene. This course we think justified on two grounds. First Russell (1930) has subjected both theories to searching examination, marshalling for the task both his own penetrating thought and that of several other recent writers, notably of W. Johannsen and F. R. Lillie. Partly because Johannsen was the originator of the term "gene" what he has to say in the article here referred to merits special consideration. The following bears particularly on the main point now occupying us:

> We are very far from the ideal of enthusiastic Mendelians, viz. the possibility of dissolving genotypes into relatively small units, be they called genes, allelomorphs, factors or something else. Personally, I believe in a great central 'something' as yet not divisible into separate factors. . . . . Disregarding this (perhaps only provisional?) central 'something' we should consider the numerous genes, which have been segregated, combined or linked in our modern genetic work. (Johannsen, 1923, p. 137.)

Reading this in the light of the concept of wholeness, the question of the relation of Johannsen's "central something" to this concept can hardly be escaped.

Really if one faces squarely the chromosomal theory of development as this now dominates genetical science, he can hardly avoid a feeling of amazement that the logical fallacy it contains could get a firm grip on so large and generally capable a group of men as that composing the modern school of genetics. For see what, in brief, a bald expression of the theory is. As one instance of telling criticism of it, take this from F. R. Lillie.

After referring to the "almost universally accepted" view that all the cells of every multicellular organism receive each a full set of the chromosomes characteristic of the species, these chromosomes containing in turn a full set of the genes of the species, Lillie writes: "It would, therefore, appear to be self-contradictory to attempt to explain embryonic segregation by the behavior of the genes which are *ex. hyp.* the same in every cell." (1927, p. 365.)

Notice what this statement, having a rather mild look from the professional language used, says when so reworded as to exhibit it in the light of the Aristotelian reasoning! All the cells of a man, let us say—cells of his bones, his muscles, his liver, his brain, his testicles, and all the rest—have the same number of chromosomes, each chromosome having samples of all the genes. And all the chromosomes (with their genes) are just alike in all the cells no matter how different the cells. Yet the chromosomes (with their genes) are held to explain, causally, the differences of the cells. Furthermore, the chromosomes (with their genes) are able to do all this despite the fact that in size they are usually but a small fraction of the complete cells. Even the entire nucleus (in which the chromosomes are situated) of a striated muscle cell for example, is minute indeed as compared with the cell itself. Nevertheless both structurally and functionally this highly complicated cell is conceived to be explained by its chromosomes (with its genes). What a telling example of Aristotle's mildly ironical remark about trying "to prove the obvious by the unobvious!" It would, I think, be hard to find in the whole range of natural

science a more glaring example of the power speculation may have to set observation at naught. To illustrate, an uncompromisingly orthodox geneticist can declare, even with his eye at his microscope watching the cytoplasm of a muscle cell transform into the characteristic, contractile part of a muscle fiber, that not the cytoplasm itself but some wholly invisible substance coming from the almost invisible chromosomes of the cell's nucleus is the real causal power or influence of what he is actually seeing! This is the very essence of the occult, and the sooner science acquires the ability to resist the primal urge in this direction the better for everybody.

Probably I have pushed the logic of the chromosome theory more rigorously than its most devoted protagonists would push it. And the reason, one may suspect, why such protagonists do not push the reasoning thus is their half-conscious recognition of its profound fallacy.

In this exhibit of the bad use of sense data in genetics have we not ample warrant for holding that the logic—the mode of thinking—of the science, is as important as the observational data? Furthermore, in view of the fact that Aristotle is the acknowledged founder of the sciences of living nature and is also the acknowledged founder of logic, is it not incumbent on at least all professional students of living nature that they should listen to him as logician as well as biologist?

It is a curious fact that speculative biology of today conceives, as we have seen, almost if not quite as sharp an antithesis between the generative elements and the structural elements of organisms as theology and philosophy have for centuries conceived between the soul and the body and as modern psychology has conceived between mind and matter.

Quite justifiably, I think, we may recognize the following observationally undemonstrated, highly speculative, and more or less mystical antitheses assumed as aids to the interpretation of human beings: between soul and body (by theology and much of philosophy); between mind and matter (by psychology and physics); and between germplasm and somatoplasm (by genetics and most of current general biology).

It would be the height of folly to plunge into these problems here, and nothing is farther from my intention. My sole object in mentioning them is to point out that my conception of a man (or any other real object) *whole*, and also Aristotle's *entelecheia* as I interpret it, give no quarter for any of these antinomies.

THE LAW OF IDENTITY

The part of the task by which we are confronted at present is that of seeing how Aristotle used a principle of logic in support of his interpretation of reproduction and ontogeny. The logical principle particularly involved is the so-called law of identity. All we need do here is to see the application of the principle to the special problem of begetting and ontogeny, though the essence of the law should be sharply in mind: If a thing is, it cannot be either more nor less *is* or any other thing; if it was, it *was*; if it is to be, it is *to be*; if it is a particular object it cannot be any *other* particular object. This all being true of every real thing, such is part of its nature, according to Aristotle. Hence, knowing as we do much more about children than Aristotle knew, we should say that trying to explain the obvious by the unobvious is not so much a childish performance as it is the performance of a bewildered mind. It is indicative of fragmental or haphazard thinking more than of immature thinking.

So we are prepared to go on and see how in accordance with the Aristotelian think-

ing the connection between the semen (germinal material, or germplasm) and the parental body (corporeal material, or somatic plasm) may be such as to make the concept of *entelecheia* applicable to the parent with all his capacities, but especially, for the point in hand, those of begetting and thinking.

We must start the discussion with a bit of repetition. For in our efforts to attain an understanding of Aristotelianism we are not likely to overemphasize the idea that the real, full nature of a thing is not found alone in either its matter or its form (in its parts or its entirety) but in the combination of these. But, as we have previously seen, from the standpoint of knowledge-getting, i.e. the epistemological standpoint, the form of a knowing organism plays a part that is entirely unique and exclusive as compared with the part played by its matter. The sense perceptive phase of knowledge-getting depends upon form in a way that has no counterpart in its dependence on matter.

In order that a body of any shape or size may do anything at all by which we recognize it as alive (e.g. grow; move in response to stimulation; crawl, walk, swim or fly; make seemingly automatic sounds; produce another like self; be aware, i.e. be conscious; act in its own interest; think; have ideas and so on and on) it is able to do these things only in virtue of the fact that certain bodies other than, and external to, itself are found when taken into the body in question, to possess qualities or properties capable of yielding to the body exactly what is necessary as material and energy, to enable it to be and do just what it is and does. That is, speaking in ordinary language, bodies which serve as nutriment for living bodies do this in virtue of certain qualities or properties which they possess in the latent condition that are actualizable only by being used as nutriment by such bodies as that in question. In other words, all activities of living organisms, including the most exaltedly intellectual and spiritual activities of man, are found, when the searchlight of modern physiology and biochemistry is turned upon them, to be wholly and directly dependent on those powers and processes common to all living beings which have been given the name metabolism.

Whether the activities be reproductive of the most simple or most complex kind; or rationally conscious of the simplest or most complex kind—all rest back finally on the metabolization of food and respiratory air. This subject has been treated in some detail (Ritter and Bailey, 1928, pp. 348–355) and considerably more fully in the earlier part of the general work of which this article is a part.

Now as Aristotle had no knowledge whatever of germ cells it was, of course, impossible for him to have any conception of heredity and genetics in a modern sense. But with such knowledge as he possessed in common with everybody else, and to which his special researches in generation had added, he was able to show in the most unequivocal way what the logical principles he had discovered would compel him to say about the natural relation between begetter and begotten—between parent and offspring. How many times and in how many of the Aristotelian writings the statement occurs that "men beget men," I have not thought it worth while to try to count. So obviously true does the statement seem that to ordinary mortals saying it at all would appear to be superfluous. Yet Aristotle evidently thought it worth saying, and saying repeatedly. Why? Because he wanted to force home the vital truth of the common experience that men with their matter, form, and all the rest come-to-be by the begetting ability of other men and not

otherwise. Notice now the character of his evidence: "Men propagate men, but bedsteads do not propagate bedsteads" (*Physics* 193^{b} 10). Nevertheless it is equally certain that both a bedstead and a man have a form, some matter, and a function, or use (one or more). Likewise it is equally certain that both have come-to-be from something which it was not originally, and by some agency. That is to say, each has with equal certainty passed from a state of potentiality to a state of actuality. Or, summing it all up, it is equally certain that each has (or perhaps better *is*) its own *entelecheia*.

Furthermore we know with equal certainty what the main producing agent was in each case. It was a man (one at least). But how different the producing activity in the two cases! In the case of the bedstead the producing was done by the producer's employment of his brain, hands, eyes, and so on. Man the producer is here an artist and the product is a work of (mechanic) art.

In the case of the man produced by a man no designing and manual activity by the producer came into the business. Here the producer's generative organs and his germinal fluid are the chief means employed. Man the producer is here not an artist but a natural cause and the product is the work not of art (as usually understood) but of nature.

Aristotle's theory that the semen is the only truly generative factor in propagation, ludicrous as we now know it to be, nevertheless furnishes conclusive proof of its author's belief that one parent at least (the male) is a real producer of the offspring and not a mere conduit, so to speak, through which the generative substance (the germplasm of the modern theory) reaches the ovum. His theory was, we notice, very nearly the reverse of that now held. For his speculation was, it will be recalled, that the semen contributes the form and soul to the embryo, while the catamenia (the female's supposed contribution) furnished the material only.

It appears certain that Aristotle's great interest in the problem of the semen—its source, its structure, its potentialities and so on—was chiefly inspired by his recognition of what has now become the problem of heredity, or genetics. For instance his penetrating conclusion already noticed, that although the semen cannot of itself contain particles from all the actual parts of the body (as some of his predecessors had supposed) it still must contain potentialities for these in so far as they are actualities in the offspring, is particularly significant. Illustrations against the representative particle theory are: "Men generate before they yet have certain characters, such as a beard or grey hair." (*De Generatione* 722^{a} 7); also, as to plants: "the seed does not come from the pericarp, and yet this also comes into being with the same form as in the parent plant." (722^{a} 15.) As an example of evidence for the potentiality theory of the semen, we may requote a passage, a part of which has already been quoted. "But if we do not say this (while saying that semen comes from all parts of the body), how will the foetus become greater by the addition of something else if that which is added remain unchanged? But if that which is added can change, then why not say that the semen from the very first is of such a kind that blood and flesh can be made out of it, instead of saying that it itself is blood and flesh?" (*De Generatione* 723^{a} 10–15.)

It is of more than historic interest to notice that had Charles Darwin been thoroughly acquainted not only with Aristotle's observations and reasoning as here illustrated, but also with the Aristotelian logic involved in the reasoning, he (Darwin) would never have put forth his famous "provisional hypothesis of pangenesis." That Darwin was not thus acquainted

with the Aristotelian writings is proved by his own reference to the matter (1899, p. 370) where the hypothesis is elaborated. In this reference Darwin tells us that G. H. Lewes had called attention to the fact that "more than two thousand years ago Aristotle combated a view of this kind, which, as I hear from Dr. W. Ogle, was held by Hippocrates and others."

To what extent if at all August Weismann, the prime mover of the modern germplasm theory, was aware that his conception of biophores, determinants and vital units, or particles of various name were subject to the same Aristotelian criticism as was Darwin's conception of pangens, I have not undertaken to look into carefully. But it is tolerably safe to assume that even though Weismann and his many followers in this kind of speculation may have been in accord with Darwin's sentiment that Linnaeus and Cuvier "were mere schoolboys to old Aristotle" (letter of C. Darwin to W. Ogle, February 22, 1882) that sentiment rested chiefly on their acquaintance with Aristotle as a "father of zoölogy" and very little if at all on their acquaintance with him as the "father of logic."

I refer to the remarks here made as being of "more than historic interest." The "more" of the reference concerns the question of the possibility that in the future attention to the science of knowledge itself may save biology from the mass of futile or nearly futile printed matter and oral discussion that in the past has been devoted to imaginary vital units.

Unquestionably the problem of how offspring come to resemble their parents and ancestors (the problem of heredity) as Aristotle saw it, was the problem of how the parent (male alone as he believed) actually does contribute characters (potential) similar to his own, to the offspring. And of particular significance is the fact that important instances of the use of the term *entelecheia* in the *De Generatione* exhibit the involvement of exactly this capacity of the parent as part of its "complete reality," i.e. its *entelecheia*. We will notice a case in point. After giving his almost hackneyed illustration of the fact that a man-made object (an axe this time) is not primarily that object because of the material which enters into its make-up or the external conditions which contribute to its making, but at least as much because of the form which the maker has given the material, we have the passage already quoted and commented on: "While, then, we may allow that hardness and softness, stickiness and brittleness, and whatever other qualities are found in the parts that have life and soul, may be caused by mere heat and cold, yet, when we come to the principle in virtue of which flesh is flesh and bone is bone, that is no longer so; what makes them is the movement set up by the male parent, who is in actuality [*entelecheia*] what that out of which the offspring is made is in potentiality." (735^b 30–35).

From more or less direct statements like this, and from his general doctrines of form and matter, of actuality and potentiality, of a whole-and-its-parts, as well as of *entelecheia* itself, there is not the least doubt, as already said, that Aristotle's theory of reproduction would make the parents real producers, genetically speaking, of the offspring, just as in common experience they seem to be. In other words his view is opposed to the modern theory of the functional isolation of the germ plasm.

We are, therefore, now confronted by the question of what more exactly, on the Aristotelian interpretation, the relation must be between the parent and its own generative substance. For this question is, it will be noticed, only a special case of the general question of the relation of any whole to its parts.

Let us restate the specific question so as to show its identification with a cardinal point in the general presentation previously made. The point referred to is Aristotle's virtual recognition that the *ontos* of ontology and of ontogeny of later times must be one and the same when a particular person is considered. Anyone who carries on the "ontological argument for the existence of God," for instance, as its

originator, Anselm of Canterbury (Anselm, 1903) did, must have gone through, long before this an extended, highly complex ontogenic process. That is to say, he had developed through the various stages of embryo, infant, childhood, youth, etc.

But more important still for the point in hand, Anselm, once he had attained adulthood, was able, if normal, to be the initiator of another ontogeny. In a word he was able to beget children. And these children might in turn become able both to carry on the ontological argument and be the initiators of other ontogenies.

> As is well known Anselm's fame rests largely on his leadership in the Realism of Mediaeval philosophy. Although we here get the merest glimpse of the man this is enough to show distinctly the difference between his Realism as a philosopher and his realism as the possible father of children. (Rogers, 1925, p. 209.)

And so we come into the immediate presence of the truth at which the concept of *entelecheia* aims. The "complete reality" of a human being, how defiant of a complete inventory are its contents! But this much is clear: The complete reality of a man or woman includes not only all of his or her own ontogenic activities but likewise all his or her ontologic activities.

Further it includes his or her possible activities as an initiator of other ontogenic activities, these having in turn the possibilities of other ontologic activities and so on indefinitely. The only questions to an attempted answer to which we are committed are those of how the same individual's ontologic activities are connected (a) with his own ontogenic activities and (b) with his potentialities for other ontogenic activities.

The first question, (a), has been dealt with in an earlier part of this book and need not detain us now farther than to remind ourselves of what was revealed as to the grounding of all our supposedly innate or uncaused or autonomous mental furnishings in sense data or stimulus-response phenomena of one kind and grade or another.

The second question, (b), is consequently what we must now grapple with. As a starter, it will be best to transcribe the question from the rather remote, philosophic terminology in which it was expressed a moment ago, into the more familiar language of psychobiology and after that into the still more familiar language of common experience.

Psychobiologically the question states itself about thus: What is the connection between one who knows objects and activities and the objects and activities themselves when these are part and parcel of his own very self?

Then, bringing the question down to the language of common experience for the special phenomena we have essentially this: What is the connection of one's knowledge of himself as a begetter of offspring and the portions of himself that are chiefly concerned in the begetting, i.e. with his genital organs and substances?

It is hardly necessary to say in so many words that regardless of whether we state the question in philosophic or psychobiologic or everyday language it appertains to the very same objective facts. But this is only another way of saying that we have to do with a special set of objective facts which, so far as we are able to think and speak about them at all, lie within the power and scope of our knowledge. And this in turn is equivalent to saying that the facts are likewise portions of our personal experience; i.e., are part and parcel of our existence as conscious beings. Thus are we brought to the crucial matter adequately discussed (we hope) (Ritter and Bailey, 1928) and in the earlier part of this work, namely, of a being that is fully con-

scious, or aware of itself as differentiated from the rest of the world, and of such a being as a very special, and for us mortals a wholly unique case of existential wholeness.

CONSCIOUSNESS AS A PHENOMENON OF WHOLENESS

A brief reminder of our general results about consciousness as a phenomenon of wholeness will probably suggest what the present inquiry is coming to.

The rule, or law at which we arrived may be mentioned: The absence from our untutored consciousness of structural and functional details, which details are discovered by scientific analysis, does not at all invalidate the testimony of our conscious experience to our existence and the dependence of this existence on these details. For example, the fact that the detailed structure and function of our nutritial system have no place whatever in our consciousness until scientific analysis puts them there, does not impair in the least the testimony of our general experience as to our nutritial needs and acts, as to the reality of our existence, and as to the dependence of our existence on the details indicated. A human organism's awareness of its need for food and, speaking broadly, of how it can satisfy that need, is basically the same when the individual is an infant two months old as when he is a physiologist thirty years old. His being a physiologist makes no difference with his being hungry and thirsty.

Now as for the infancy stage of the organism whatever the anatomical-physiological locus of, and stimulus to his awareness concerning food and drink (the rhythmic contractions of the walls of the stomach for example) two inferences concerning the phenomena seem unescapable: (a) the actual seat of the need is all the organs and tissues of the organism and not some particular organ and tissue to the exclusion of all others; and (b) the obvious wholeness of what we name our conscious states must be such as to correspond somehow to these felt needs and to the satisfying of them.

But since such consciousness, or awareness, is more basic than, and is independent of, anything scientific analysis discovers concerning the needs and corresponding actions, the analytical results must be in harmony with the needs and relevant actions and also with the conscious states corresponding thereto. This means that were the analytical results to be in any way disharmonious with the needs such results would necessarily be as thus judged, untrue, or false. For instance, were analysis to make discoveries which seemed to justify an hypothesis that some tissues, of nerve trunks for instance, have no need of nutritive materials and thus do not fall within the scope of conscious states appertaining to nutritial needs and acts, putting of the hypothesis to rigorous practical test would result finally in the death of the experimented part.

Furthermore, the hypothesis would, because of its disaccord with the known facts of nutrition and metabolism, be a perpetual challenge to critical biology.

Now the truth is, as biologists know, this illustrative situation has actually happened. Only by the most refined research methods of the last few decades has it been possible to bring nerve action into metabolic accord with the action of other tissues. And, our point here is, this tissue is thus brought to the same status in the general conscious life of the organism as all other tissues. That is to say, scientific analysis applied to man, if sufficiently searching, finds itself in accord not only with general scientific knowledge, but also with the general consciousness of the human organism.

Is it not now clear what we are coming to on the problem in hand? The proposi-

tion indicated is that the generative organs and tissues of the parent hold a relation to the organism as a unified whole that is not basically different from what all other organs and tissues hold to it; and consequently that if ever scientific analysis becomes searching enough the germplasm will be found to be no exception to the known integratedness of all other plasms of the organism in both its physical and its psychical aspects. Otherwise stated, sufficiently close analytical research will almost certainly discover that germplasm and somaplasm present no contradiction to the idea of complete reality (*entelecheia*) of organisms, as, according to prevalent genetic theory, they do present.

It is instructive to note that extreme analytical theorists, that is to say, extreme particleists in biology have said time and again that we really ought not to say a person digests, thinks, and so on, but that the cells of the digestive tract, of the brain, and the rest of which the person is an aggregation, digest, think, and the rest. It should be recognized that the prevalent germplasm hypothesis is logically and biologically at one with such views.

This whole subject is so overflowing with human interest and human welfare that at the risk of incurring criticism for prolixity, I am going to treat it illustratively a bit farther.

In the earlier part of this work when dealing with the pseudo-question of proving by logic one's own existence we utilized Napoleon Bonaparte in an illustrative way.

The same man may be requisitioned to help us with the germplasm- somatic-plasm puzzle.

Can anybody doubt what Napoleon's reply would have been had he been questioned concerning his relative belief in his own existence as the begetter of his children and his belief in his germplasm which, by means of its potentialities, contributed to the nature and characteristics of, say, his son Francis Charles Joseph?

But, would promptly come from an orthodox geneticist, Napoleon was no biologist, so of course knew nothing about the reproductive elements in the sense of modern genetics. His supposition that he as a somatic self actually contributed to his son's hereditary characters was only an instance of the error into which unscientific experience and belief have always fallen on this matter.

To this Napoleon might have replied that all the experiences of his entire life, including his knowledge of his bodily members and his activities, and all his emotions, his sex passions by no means excluded, were his very own as a living, conscious being. Furthermore, he might have continued, an essential part of this experience and knowledge has been that in order thus to have experience and to know, he must breathe, eat, and drink; and further that all his experience and knowledge strongly indicate that there is no part or action of his which does not depend on the materials taken into himself by the functions mentioned.

That is to say, even Napoleon, wholly uneducated in the niceties of genetics and physiology though he may have been, was nevertheless competent to take the unassailable position that there is no justification in a theory of the individual man or woman that would make some particular living part thereof less essentially a participant in, and dependent on, the life of the whole organism than is any other part.

So far, I say, anybody, resting on the foundation of common experience and common knowledge may go with Aristotle in opposition to the isolation theory of the germplasm, and in support of this concept of *entelecheia*.

(*To be continued*)

LIST OF LITERATURE

ANSELM, ST. 1903. Proslogium. Religion of Science Library, No. 54. The Open Court Publ. Co. also ROGERS, A.K. 1925.

BELLING, JOHN. 1931. Chromomeres of liliaceous plants. Univ. of Calif. Publ., Botany, Vol. 16, No. 5, pp. 153–170.

BURNET, JOHN. 1900. The Ethics of Aristotle.

BUTCHER, S. H. 1911. Aristotle's Theory of Poetry and Fine Art. (4th Ed.)

DARWIN, CHARLES. 1899. The Variations of Animals and Plants under Domestication. Vol. II. 2d Ed.

DENDY, ARTHUR. 1922. Outlines of Evolutional Biology. 3d ed.

DRIESCH, HANS. 1914. History and Nature of Vitalism.

———. 1922. Geschichte des Vitalismus. 2d Ed.

———. 1931. Mitwirkung von Heinz Woltereck. Das Lebensproblem im Lichte der modernen Forschung.

DURANT, WILL. 1926. The Story of Philosophy.

GRANT, SIR ALEXANDER. 1885. The Ethics of Aristotle. (4th Ed.)

HARRIS, W. T. Webster's Dictionary.

HICKS, R. D. 1907. Aristotle, De Anima.

JAEGER, WERNER. 1923. Aristoteles: Grundlegung einer Geschichte seine Entwicklung.

JOHANNSEN, W. 1923. Some remarks about units in heredity. Hereditas, IV, 1923, 133–141.

LILLIE, F. R. 1927. The Gene and the Ontogenetic Process. Science, Vol. 66. pp. 361–368.

OGLE, WILLIAM. 1911. De Partibus Animalium.

PETERS, F. H. 1893. The Nichomachean Ethics of Aristotle. (15th ed.)

PLATT, ARTHUR. 1910. De Generatione Animalium.

RITTER, WM. E. (with the collaboration of Edna W. Bailey). 1927. The Natural History of our Conduct.

RITTER, WM. E., and EDNA W. BAILEY. The organismal conception, its place in science and its bearing on philosophy, University of California Publications in Zoology, vol. 31, No. 14, 1928, pp. 307-358.

ROGERS, A. K. 1925. A Student's History of Philosophy, new ed.

ROSS, W. D. 1908. The Works of Aristotle, Vol. VIII. Metaphysics.

RUSSELL, E. S. 1930. The Interpretation of Development and Heredity.

SMITH, J. A. 1931. The Works of Aristotle, Vol. III. De Anima.

STOCKS, J. L. 1922. Aristoteles, De caelo.

THOMPSON, D'ARCY W. 1910. The Works of Aristotle, Vol. IV. Historia Animalium.

WALLACE, E., 1882. Aristotle's Psychology.

WEBSTER, E. W. 1923. The Works of Aristotle, Vol. III. Meteorologica.

WICKSTEED, P. H., and F. M. CORNFORD. 1929. Aristotle, The Physics, Vol. I.

WINDELBAND, W. 1905. A History of Philosophy. 2d ed.

WOODRUFF, L. L. 1923. Fundamentals of Biology.

BIOLOGICAL PECULIARITIES OF OCEANIC ISLANDS

By ADDISON GULICK
University of Missouri

THE present paper has grown out of a survey of the literature on the zoo-geography of the Hawaiian Islands, undertaken in connection with the preparation of an account of the zoölogical studies of John Thomas Gulick. The immediate objective was evidence of any sort bearing on the evolutionary antecedents of endemic insular genera.

One of the most challenging of all questions in animal and plant distribution is the problem of the peopling of remote oceanic islands by appropriate forms of terrestrial life; and the peculiarities which we find in such island populations probably furnish valuable clues toward the elucidation of more than one of the laws of organic evolution.

How is it possible at all for creatures that would die almost at the touch of sea water to precede man by a million years on islands standing solitary in mid-ocean? Are their remote homes really the left-over fragments of ancient inter-continental land bridges, or are these creatures *prima facie* evidence that their ancestors possessed an almost inconceivable capacity for passing uninjured over vast stretches of open ocean? The extremes of hypothesis that have been proposed in response to this dilemma show us how difficult it has been to find a reasonably credible solution.

At the present time scientific writers are fully agreed only as to a very limited number of unmistakable oceanic islands—islands, that is, whose terrestrial fauna acknowledgedly cannot have arrived by the land-bridge method. Unfortunately, the majority of these localities are but very imperfectly studied, because of their inaccessibility, and several of them suffered heavily at the hands of human inhabitants before scientific collectors could arrive.

THE FLORA AND FAUNA OF EASTER ISLAND

Aside from mere sand-spits and bird rocks, the most solitary of all high islands is undoubtedly Rapanui, or Easter Island (32, 31, 12), the easternmost outrider of Polynesian colonization. This lonely triangle of volcanic cones and dead craters, with some 45 square miles of land surface, is the wave-worn remnant of an island that could once have claimed about twice that area (31). It looms above the horizon at a distance of 2,280 miles west of the South American coast, and 1,590 miles east of the tip of the Paumotu Archipelago, where begins the mid-Pacific zone of multitudinous islets known as Polynesia. The only near neighbor of Rapanui on this vast expanse is a trivial bird rock, 250 miles to the east. Other neighbors, more distant, are Ducie, an uninhabited atoll lying 1,000 miles westward, Pitcairn 1,300 miles, more or less, in the same direction, and the South American islands of Juan Fernandez and Mas-afuera, which are respectively 390 and 450 miles from the Chilean coast.

Being inhabited for many centuries by a Polynesian tribe (12), the native flora and fauna of Rapanui have doubtless suffered both losses and additions through artefact. Domestic fowl quite certainly, and rats most probably, came to it as fellow pas-

sengers with the Polynesians in their ocean craft, furnishing its only known examples of land birds and quadruped mammals. Any other land birds, if they ever existed, have been so long extinct that the natives have no memory of them. Thus we may perhaps have here one of the ultra-rare cases of a high island that has never been colonized by any passerine birds.

The pre-European flora was judged by Knoche (31) to consist of 55 species, representing 50 genera. Skottsberg (52) reviews the list more critically, and is only inclined to credit 30 of the flowering plants, representing 26 genera and 15 families as genuine ancient inhabitants, and 6 species from 6 genera as Polynesian introductions. To these may be added 12 species of ferns, two of them endemic and ten more widespread, which are not supposed to have been brought by man. He marks down all other vascular plants thus far reported from Rapanui as late introductions.

None of the genera are peculiar, and no two endemic species are of the same genus. In short the flora is, as Baur (3) would express it, emphatically "disharmonic," meaning by this that its species lack the local coherence of inter-relationship, and that the assortment of forms fails to constitute a normally balanced and diversified total flora. The affinities are largely with the Polynesian region, although three of the pre-human species are counted as American. Only two ferns, three grasses and one tree are credited as endemic species, all the others being known from other parts of the world. As compared to other islands the plants introduced by Polynesian navigators are unusually few, although the legends of the natives claim that the entire flora of Rapanui was brought here by their heroic ancestor.

The trade winds and ocean currents, as we now observe them, come to Rapanui consistently from the east, but the carrying power of hurricanes in this mid-Pacific zone is believed to be predominantly from the west. Hence the impossibility of drifting mangrove seeds reaching here from western Micronesia, where they are native, and the apparent failure of cocoanut palms to arrive here before their planting by man (30). Yet wind-borne seeds, quite incapable of traveling 2,000 miles upon a trade wind, must have been brought repeatedly by storm winds from Polynesia, as shown by the general affinities of the flora.

The supposedly native insects (35, 16, 11, 68) are limited to a weevil, apparently endemic, and two aquatic Neuroptera, one of them a South American form, and the other not reported outside of this island. Unfortunately the insects of other parts of the Pacific are not yet sufficiently known to make it certain that either of the two seemingly endemic species are genuinely peculiar to Rapanui.

Among land snails (36) the outstanding occurrence is an endemic species and possibly genus known as *Pacificella variabilis*, measuring when adult about 3.8 mm. long by 1.5 mm. in diameter. It is related to the Tornatellinidae of Polynesia and Juan Fernandez. One other species, *Melampus paschus*, is included as an endemic form, belonging to a Micronesian and Indonesian genus that is very tolerant of exposure to salt water. The list of land snails is completed by two commercially widespread slugs and an Indonesian species of *Melampus*, which also falls under suspicion as a possible introduction.

Aside from the usual pests that come on ships, the remaining items in the land fauna are two Polynesian lizards, a South American earthworm (34), one or two butterflies, a Polynesian cricket, a scanty list of beetles (more especially an earwig and a water beetle), and certain well-known "tramp" species of ants (65), spiders (4),

myriapods (61), etc. It is doubtful whether any of these were here before man, but impossible to prove that some among them may not have been.

The significant points in these not very complete data are:—

(1) The flora is emphatically "disharmonic," revealing that life here is definitely insular, and not ascribable to land-bridges.

(2) The fauna is not only "disharmonic" but excessively meager and scrappy, and does not show a very high degree of species differentiation. In only one instance is there a suspicion that differentiation has reached a generic level, and for that genus only one species has been reported. As this means a relatively young fauna, and the geology favors a fair antiquity for the island, there is more or less reason to suspect (1) that the ancestors of most of the pre-human species now found there arrived since the date of some cataclysm, such as a devastating volcanic eruption.

(3) Despite its extreme remoteness, this island was successfully colonized by a number of plants and a few animal forms, more especially one or two snails and apparently a scattering of insects. Thus it is evident that some forms of life can find their way across vast stretches of ocean without human intervention.

FLORA AND FAUNA OF CHRISTMAS AND OTHER ISLANDS

West and south of the Hawaiian Islands are a number of remote islands, some occurring sporadically, others stretched out in loose alignments along two submarine ridges. A tabulation is presented here of the flora of Palmyra, Washington, Fanning, and Christmas atolls, lying somewhat grouped at a distance of 1,000 to 1,300 miles south of Hawaii (10). Obvious human introductions have been omitted, but doubtful cases such as the cocoanut have been included. It will be seen at once that these floras are disharmonic, as is becoming for islands dependent on the seeds brought by winds, waves, and birds, but that a certain degree of orderliness exists, inasmuch as fully two-thirds of the plants listed are found on more than one island, and about a third of them are found on three or more islands. This shows that plants able to reach the group at all are fairly likely to jump the gaps of 50 to 100 miles between atolls. The fauna, other than marine turtles and sea birds, has not been worked up, but there is reported to be a significant assortment of minute snails, about which group more shall be said presently.

Marcus Island, visited and described by W. A. Bryan (7) seems to be radically oceanic, with some features worth noting. This bit of lifted reef, 75 feet high and less than a square mile in extent, including its dried lagoon, lies 2,400 miles west of Honolulu, about 1,200 miles southeast of Yokohama, and perhaps 1,000 miles northeast of Guam. The nearest of the Ladrone Islands are at a distance of 600 miles. Although the soil and moisture on Marcus Island are favorable, there seem to be not over a dozen plant species, and unusually few insects—a vinegar fly, a blowfly feeding on sea-bird carcasses, a small miller, and one cosmopolitan species of spider. No passerine birds were found, nor did it seem likely that any could find adequate nourishment if they should come. Both earthworms and snails seemed to be nonexistent. And yet two Polynesian species of lizard were observed—a gecko and a skink. All told, the island seems to be faunistically very young. The most notable points were the presence of the lizards and the apparent absence of mollusks, even of the diminutive species. There were no

obvious evidences of man, except of recent date.

Extending for about 1,500 miles west-northwest from the major islands of the Hawaiian group runs the Laysan-Midway Island chain (8), a desultory string of all been originally volcanic cones, eroded or subsided, until most of them now consist of more or less circular coral reefs. One or two of these coral rings measure at least 18 miles across, as a witness to the possible size of the volcano that has been

TABLE 1

Résumé of Vegetation on Christmas Island Group

	PALMYRA		WASHINGTON		FANNING		CHRISTMAS		TOTALS		SUPPOSED MEANS OF INTRODUCTION
	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	
Polypodiaceae	2	2	3	3	1	1			3	3	Wind
Lycopodiaceae			1	1					1	1	Wind
Pandanaceae	1	2	1	2	1	1			1	3	Water
Naiadaceae			1	1					1	1	Birds?
Gramineae	1	1	1	1	1	1	3	3	3	3	Water?
Cyperaceae			2	2	1	1			2	2	Birds? Water?
Palmae	1	1	1	1	1	1	1	1	1	1 or 2	Water
Urticaceae			1	1					1	1	Birds? Water?
Nyctagenaceae	2	2	2	2	2	2	2	3	2	3	Birds? Water?
Aizoaceae					1	1	1	1	1	1	Water
Portulacaceae	1	1			1	1	1	1	1	2	Birds? Water?
Lauracaceae			1	1	1	1	1	1	1	1	Water
Cruciferae	1	1	1	1	1	1	1	1	1	1	Birds? Water?
Leguminosea			1	1					1	1	Water
Simarubaceae	1	1	1	1	1	1	1	1	1	1	Water
Tiliaceae					1	1			1	1	Water
Malvaceae					1	1	1	2	1	2	Water? Birds?
Apocyanaceae	1	1							1	1	Water
Convolvulaceae	1	1	1	1	1	1			1	2	Water
Boraginaceae	1	1	1	1	2	2	2	2	2	2	Birds? Water?
Rubiaceae							1	1	1	1	Birds? Water?
Goodeniaceae			1	1	1	1	1	1	1	1	Water
Total Families	11		16		16		12		22		
Total Genera	13		20		18		16		29		
Total Species	14		21		18		18		35 or 36		
Families lacking on other Islands	1		4		1		1				

insignificant volcanic rocks and sandy atolls. The individual reefs and islands being separated from each other by deep-water stretches of 50 to 200 miles, it is possible for each bit of land individually to function as a partially independent oceanic island. These represent discrete land masses of considerable antiquity, having demolished through slow geologic processes. Although not in the chain, we may group Johnston Island with these for tabular comparison. Johnston is a small atoll 717 miles southwest from Honolulu, and approximately 500 miles from the nearest of the islands just mentioned. It rises from a region of deep sea. Our tabu-

lations of Coleoptera and Diptera are from data in a study by E. H. Bryan, Jr. (5), and serve as representative samples out of the insect life which he studied much more extensively. Unlike Nihoa, which is a small high island 120 miles from the Hawaiian group, the insect assemblages on these remoter islands do not seem to be particularly satellitic to the Hawaiian zone of life.

Anthomyidae, and again of the coleopteran family Staphylinidae.

Laysan is perhaps the most interesting of these lands, as it is the exclusive home of the Laysan rail, a flightless bird not particularly close to the Hawaiian flightless rail; the miller bird, *Acrocephalus familiaris*, whose nearest relatives are in eastern Asia; the Laysan "finch," a distinctive genus belonging to the seed-eating branch

TABLE 2

Summary of Coleoptera found on the Hawaiian Leeward Chain of Low Islands

	FRENCH FRIGATE		LAYSAN		LISIANSKY		GARDNER		PEARL AND HERMES		MIDWAY		OCEAN		JOHNSTON		TOTAL ON EIGHT ISLANDS	
	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.
Carabidae			1	1													1	1
Staphylinidae			1	1							1	1	1	1			3?	3
Coccinellidae	1	1	1	1					1	1			1	1			1	1
Cucujidae			2	2					1	1			1	1			2	2
Dermestidae	1	1	2	2	1	1			1	1	1	1			1	1	2	2
Histeridae															1	1	1	1
Elateridae											1	1					1	1
Anobiidae															1	1	1	1
Scarabidae			1	1									2	2			2	2
Tenebrionidae			2	3					1	1			1	1	1	1	3?	4
Anthribidae													1	1			1	1
Cerambicidae			1	1													1	1
Curculionidae	1	2	6	8					1	2	3	3	2	2	2	2	6	10 (1 sp. new, from 2 is.)
Total Families	3		9		1				5		4		7		5		13	
Total Genera	3		17		1				5		6		9		6		25	
Total Species	4		20		1				6		6		9		6		30	

If insects are a criterion, it is evident that these islands are oceanic, with a disharmonic fauna, consisting of importations that were influenced partly by special ability to colonize distant atolls, partly by freaks of chance. Thus certain parasitic and carrion flies are quite widely distributed. On the other hand, three different islands have by chance received three different species representing three different genera of the dipteran family of the Hawaiian family Drepanididae; and finally the Laysan honeyeater, which is also a drepanid, but congeneric with the Hawaiian *apapani* or honeyeater.

The only wingless terrestrial invertebrates of which I find record are a couple of minute land snails, comparable to those on the Christmas Island Group. One of these, *Tornatellides bryani*, is a species limited to Laysan, and the other, *Tornatellina gracilis*, is a little slender shell measur-

ing 3 mm. by 1 mm., found on this island and on the major Hawaiian Islands.

All these low islands of the Pacific Ocean, regardless of what their geological age may be, are young as regards their flora. The plants they possess are but few of them peculiar, having reached their present phase of evolutionary development elsewhere and arrived here either by virtue of special aptitude or by some rare freak of chance. Freakish omissions of particular plants from certain local floras tend to indicate that the distribution has been by the accidents of wind or wave, not by normal spread along pre-existent land bridges. It may be tentatively predicted that the rather long list of supposedly water-borne plants will be cut shorter when due allowance has been made for aboriginal travelers, etc. The tremendous prehistoric dispersal of useful plants, such as the sweet potato, yam, taro, breadfruit, banana, *Cordelyne*, paper mulberry, candlenut, and a host of others, warns us not to be too confident that the equally useful cocoanut and pandanus may not also have depended on man for transportation in directions opposed to the major ocean urrents.

The fauna on these remote groups, so far as it is known, seems relatively maturer than the flora. Peculiar species of insects,

TABLE 3

Summary of Diptera found on the Hawaiian Leeward Chain of Low Islands

(Two obviously introduced species are omitted)

	FRENCH FRIGATE		LAYSAN		LISIANSKY		GARDNER		PEARL AND HERMES		MIDWAY		OCEAN		JOHNSTON		TOTAL ON EIGHT ISLANDS	
	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sy.	Gen.	Sp.
Chironomidae			1	1													1	1
Mycetophilidae											1	1	1	1			1	1
																	new sp.?	
Stratiomidae			1	1													1	1
Phoridae			1	1	1	1			1	1							1	1
Dolichopodidae	1	1	1	1	1	1					2	2	2	2			4	4
Syrphidae															1	1	1	1
																	new gen. & sp.?	
Sarcophagidae	1	1	1	1					1	1	1	1			1	1	1	1
																	new sp.	
Calophoridae			1	1					1	1	1	1	1	1			1	1
Anthomyidae			1	1							1	1	1	1			3	3
Ephydridae			1	1	1	1											2	2
Borboridae			2	2	1	1					1	1					2	3
																	one introd?	
Agromyzidae							1	1	2	2	1	1			1	1	3?	4
Oscinidae					1	1					1	1	1	1			1	1
																	bird parasite	
Hippoboschidae	1	1	1	1	1	1									1	1	1	1
Total — Families	3		10		6		1		4		8		5		4		14	
Total — Genera	3		11		6		1		5		9		6		4		23	
Total — Species	3		11		6		1		5		9		6		4		25	

more especially beetles, are reported on various of the islands. Laysan, for which nothing remarkable has been reported botanically, is the home of four unique birds, and of at least one land snail. It is clear that the building of animal species has far outspeeded that of plants.

THE FAUNA OF BERMUDA

When we turn to faunistically ancient islands and archipelagos, the analysis of the observed facts becomes more involved. Those least difficult to elucidate are the unitary land masses, for which Bermuda and St. Helena may serve as type examples.

Bermuda (62, 49) was anciently a volcanic cone exposing about 200 square miles of territory above water. Through erosion and subsidence all volcanic material has been lost from view, and a ring of calcareous sand hills substituted. Finally a subsidence of 200 feet or more, apparently of Pleistocene date, has reduced the present land area to approximately 19 square miles. Marine deposits of two different Pleistocene ages mark periods when the land surface may have been even more limited (49). However, the subsidence never went far enough to wipe out more than a part of the ancient fauna, the local development of which we must indubitably refer back to the ancient forest-clad volcano.

Five miles from the southwest tip of the old Greater Bermuda lay a second island (now the Challenger Bank) some four or five miles long and broad. At about an equal distance beyond this bank in the same direction was a third island (now the Argus Bank), slightly smaller still. It is not likely that this pair of satellites modified very heavily the unitary character of the Bermudian fauna.

Being only 575 miles from continental North America, and 830 miles from Porto Rico, the plant life of Bermuda is not very distinctive. Out of 156 native species, 8 are counted peculiar. About 30 species are definitely North American contributions, approximately the same number definitely West Indian, and all the remainder might have come equally well from either province.

Among vertebrates there are 7 species of resident land birds representing 7 American genera. They were formerly all considered identical with United States forms, but the dove, the bluebird and the white-eyed vireo have now been defined as specifically distinct, and 3 of the others are considered local varieties. Migrant land birds from the Nova Scotian region are frequently seen, but do not stay to nest. Bats also make visits from time to time, but are stated not to have become resident. The only other Bermudian vertebrate is a skink with a peculiarly slender snout, quite distinct from those known elsewhere, and to all appearances an endemic form.

Commercial importation of plants from many parts of the world has wrought sad confusion in our list of the invertebrates of Bermuda. Ants, beetles and other insects have arrived in great variety. Potted plants have undoubtedly introduced diverse worms and snails. One European snail, *Rumina decollata*, coming in some such way, has grown into a positive pest. Furthermore, many of the indigenous species have doubtless perished unrecorded, through the activities of hogs, rats, and ants. Out of this we can salvage the information that Bermuda had a moderate list of endemic animal species, in which are found a cicada, a few beetles, at least one ant, a couple of myriapods, various isopods, one or two worms, and an interesting assortment of snails. Several living riddles are here represented:—among the isopods are three of the supposedly peculiar Bermudian species, representing three

old-world genera; also a nemertian, again of a species not known elsewhere, but of a predominantly East Indian genus. It is hard to say how many cases we have here of ancient survivals on a protected island, and how many instances of accidental commercial importation out of lands not yet fully surveyed for invertebrates.

Bermudian snails present a more usable picture (41, 19, 56, 57, 58, 38, 39, 40), as it is possible to list them on the basis of fossil beds that must antedate human interference, and study them against the background of a reasonably well known world fauna of these easily collected specimens. Fossils and sub-fossils, probably mostly of Pleistocene age, reveal an old fauna from which some 20 species are known. One or two species found living in Bermuda, but not yet observed among fossils, may probably belong also to the old fauna. In sorting this list of snails we find 10 or 11 species of "small truck," representing 8 genera and including 6 or 7 endemic species distributed among 5 genera. Most of these have a North American aspect, but there is one, *Kaliella turbinata* (19, 56), whose generic affinity is definitely Old-World. The last-named presents a real problem. It was originally described as *Euconulus turbinatus*, Gulick, but was later collected alive by Vanatta, and assigned to its true genus on the evidence of its radula. Its presence in a crevice deposit mixed with extinct Pleistocene forms leads to the inference (but not as yet absolute proof) that the species is aboriginal to Bermuda. If it was imported by man, its original home is thus far undetermined.

The next snail for consideration is *Succinea bermudensis*, rather in a class by itself, the Succinidae seeming hardly small enough to count as wind-storm migrants, nor yet endowed with a shell adequate to render them good drift-wood passengers. Yet like skinks and geckos, the Succinidae have, in various parts of the world, an unexplained propensity for turning up on islands where one would not expect them.

Lastly and of greatest interest among the land snails of Bermuda, is the genus *Poecilozonites*, having 9 fossil species of not less than Pleistocene age, and 13 recognizable named forms. Four of these species are still living, with more or less varietal differences. In their soft parts the lack of a pedal groove differentiates them readily from other Zonitidae, but the internal anatomy nevertheless indicates a close affinity to the American genus *Gastrodonta*. There are three subgenera, (1) *Gastrelasmus*, rather small, with teeth in the mouth of the shell; (2) *Discozonites*, without the teeth, with relatively rounded aperture; and (3) *Poecilozonites*, *sensu stricto*, larger, without teeth, with a more angular aperture. The size range of adult shells is from about 10 mm. to 45 mm. or more across. In form they range from chunky turret-shaped to almost discoidal. The largest species were exterminated at the level of a definite geological horizon (49), the date being provisionally correlated with the beginning of the Illinoisan phase of American glaciation.

The introduction of a genus like *Poecilozonites*, *s.s.*, by winds or waves seems at first glance thoroughly unthinkable, but the mystery vanishes when we remember that the whole genus was doubtless developed locally from a single stock, beginning with an original introduction that is probably most nearly represented by the little *Gastrelasmus*.

If this interpretation of the relationships of *Poecilozonites* is sound, it leads to one or two interesting evolutionary correlaries. Remembering that some form of segregation is essential, wherever one species is to become the ancestor of a divergent multiplicity of species and subgenera (48, 22, 29, 20), and that these free-creeping

terrestrial forms have developed within the confines of a fairly compact territory measuring not over 18 by 12 miles, it seems highly probable that the necessary degree of segregation was supplied in this instance by differentiation of station, instincts, and reproductive physiology, rather than by the geographical factors that usually predominate in a more complex topographical setting. Thanks to these and the other evolutionary factors, a meagre and originally disharmonic faunula could supply the biological wherewithal for the establishment of a sort of insular microcosmos which had produced within itself a new partially harmonic taxonomic situation. Such a locally achieved harmonic fauna is often easily confusible with the traits of an imported continental fauna, but its true interpretation is, I believe, the very contrary situation of prolonged, isolated insularity.

THE FLORA AND FAUNA OF ST. HELENA

The forms of life on St. Helena (63) exemplify the same points as have been noted for Bermuda, but much enhanced. It is in a far more remote location than Bermuda, being over 1,100 miles from the nearest point in Africa, and nearly twice that distance from South America.

The botanical picture on St. Helena is stated to represent considerable antiquity, with suggestions of both African and South American elements. Von Ihering, who was quite consistently inclined to land-bridge hypotheses, argued that the flora here found could scarcely be explained otherwise than as a surviving fragment of a temporary, geologically ancient strip, uniting the two continents.

The fauna, however, points entirely to another conclusion. Excepting for a single land bird—the so-called wire-bird,—there is no terrestrial vertebrate of any description. Among invertebrates only weevils and snails are present in any wealth. Barring human introductions, 129 species of Coleoptera have been reported from St. Helena, 128 of them peculiar to this one area of 47 square miles (67). Over two-thirds of these are weevils, mostly wood borers. The snails (53) belong to the ancient but still flourishing families of Pupillidae, Endodontidae, Bulimulidae, and Succinidae. The first three families are widely characteristic microfaunal elements. The Succinidae we have already noted for their disconcerting ability to plant themselves where not expected. There are three endemic species of the latter, while in the first three families most of the forms belong to distinctive local subgenera, possibly actually genera. The richest single genus is *Helenoconcha* (42), in the Endodontidae, credited with 12 species. The archaic complexion of the snail fauna is not necessarily very significant, as younger continental forms do not for the most part yield minute, easily wind-blown species. But it is in any case evident that both snails and weevils have inhabited St. Helena so long that through them a harmonic aspect has been achieved in a fauna which can only have been extremely fragmentary at the start.

THE COLONIZING ABILITY OF DIFFERENT FORMS

Complex island clusters, such as the Azores (63) the Galapagos, and the Hawaiian groups present us with a series of pictures too intricate for effective portrayal in the limits of this paper. We must not attempt to do much more, therefore, than to determine the extent of applicability of the principles which simpler fields of observation have made clear, and to draw a few of the more obvious conclusions.

It is evident that mature groups of islands will attain an internal harmony,

from the standpoint of the systematist. But this harmony, instead of reflecting the pre-existent harmony of some continental source (as in the case for continental islands or land-bridge remnants) will be recognizably derivable by descent from a quite limited number of original importations, at the start distinctly miscellaneous and "disharmonic," as was observed to be the condition in Bermuda and St. Helena. Large series of previously related or previously associated forms will be found from the beginning on continental islands, but their counterpart must be brought into existence *de novo* if the group is truly oceanic. But this distinction, obvious in theory, is in practice very difficult to recognize, unless the oceanic condition is really extreme.

It is possible to go far toward a first diagnosis of the degree of a land's oceanic insularity by noting how exclusively it is peopled by types with a known capacity for colonizing across vast expanses of ocean. Our summary up to this point reveals very nearly which these forms may be. Quite a majority of them, both plants and animals, show characters that harmonize with wind-storm transportation. A respectable minority like the large-seeded palms and some tough-lived earth-inhabiting invertebrates, suggest transportation by water or on drift-wood. Such seeds and invertebrate eggs as can withstand the digestive tract of a bird (23), have a very substantial traveling radius by that means, easily 500 miles in the routine seasonal migrations, and possibly stretching in the extremest cases to almost trans-oceanic distances. It can hardly be doubted that some carrion-feeding insects have been distributed by adhering to sea birds. It stands out that large, soft-skinned creatures invariably make a poor showing. Frogs, salamanders, large mammals, and large helices exemplify this disability so excellently that their failure to arrive is a sort of negative criterion for insularity. Dioecious plants and separate-sexed animals are statistically at a disadvantage, as compared to the reverse condition, because of their poorer chance of achieving fertilization. The ability to take the journey in a gravid condition helps the chances greatly. Thus for the most part only those snails will colonize in distant islands that are small enough for wind transportation as adults. We may apparently expect snakes to establish themselves on islands within range of a reasonable passage on drift-wood, meaning by reasonable, among other conditions, the possibility of starting after fertilization and arriving ready to lay. The Hawaiian Islands are by no stretch of imagination within such reasonable range, either for land snakes on a drift-log, or for free-swimming water snakes. Marine coral-reef snakes of the southern Pacific are on rare occasions found along the Hawaiian shores, but they have apparently never effectively colonized there. It may well be surmised that one reason for their failure is the impossibility of arriving ready to lay fertile eggs. A highly efficient sensory equipment for discovering a mate at the end of the journey seems to have enabled a number of different land birds to rise above this difficulty, as a reef snake could not do.

THE COLONIZATION OF SNAILS

Minute land snails figure so frequently in the life of remote islands that it seems *à propos* to single them out for special discussion. The average amateur naturalist is practically unaware of the great world-wide array of these little shells, none of which ever grow big enough to weigh 0.1 gram, while many of the species are completely grown and beautifully perfect at a shell size of less than 1 millimeter over

all, and with a live weight of less than 1 milligram. Collectors usually lump them all together as "small truck," but the enthusiastic "malachologist" brings them to notice under such ponderous expressions as "molluscan faunula" or "pulmonate micro-fauna." Many families of gastropods play a part in the world's faunula. The islands of the Pacific are well stocked with certain cosmopolitan families,—Pupillidae, Zonitidae, and Endodontidae, but they are more particularly rich in the last-named group, together with the special Pacific insular family Tornatellinidae, and also the Streptoneurous shells that are classed as Helicinidae, and derived independently from an ancient seashell origin. The Helicinidae, unlike the Pulmonata, to which the others belong, have separate sexes. The Pulmonata are hermaphroditic, but require copulation, accomplishing the act usually in a mutual manner that permits both individuals to develop fertile eggs or young. In any of these families a single gravid hermaphrodite or female transported to a new location may become the parent of a new colony. And, as such a gravid adult weighs extremely little, it is comprehensible that a hurricane may at times spread these creatures like dust and small rubbish over almost as great a distance as plant seeds can be blown.

The possible maximum distances of such transportation are worth considering. Bermuda, the Azores, and St. Helena have these little snails in abundance, including distinctive genera or subgenera in each of these places. Even Tristan da Cunha, over 1,500 miles distant from Africa, 2,000 miles from South America, and believed to possess no other native land creatures except three birds and a few insects, is the home of a couple of little snails, for which the genus *Tristania* has been erected (44). In fact it is easier to list exceptions than examples, for among islands reasonably provided with earth and plants, we have learned of but one in the Pacific Ocean, Marcus Island, that is supposed to lack these micro-pulmonates, and only one in the Atlantic, Ascension Island, where the as yet inadequate reports seem not to include any mention of them.

But apparently the greatest demonstrable milage outstrips all of the above. Juan Fernandez, 390 miles from Chile, where Alexander Selkirk suffered his famous exile from mankind, has a micro-fauna of which at least three elements (36) can have derived their ancestry only from Polynesia, fully 3,400 miles away, unless Easter Island served as a way station. These forms are *Tornatellina conica*, found only in Juan Fernandez, but recognizable as a member of a definitely Polynesian genus; *Tornatellina bilamellata*, known with certainty only from this island, though doubtfully stated to occur also in Rapa, 3,880 miles away; and the genus *Fernandesia*, comprising about ten endemic species, revealed by its anatomy to be of the Polynesian Tornatellinid ancestry. Competing with these as a long-distance traveler is *Tornatellides chathamensis* (14) of the Galapagos Islands, derived of necessity, it would seem, from the Hawaiian-Polynesian zone of life, distant 3,300 miles across uninterrupted deep ocean, if we count from the Marquesas, or 2,150 miles if we suppose its ancestor to have come north from Easter Island. If the Bermudian *Kaliella* finds confirmation as a Pleistocene fossil, the problem of its dispersal will become much like that of the Galapagian *Tornatellides*.

Frankly, as a contribution to the windstorm hypothesis, such distance records are marvelous to the point almost of embarrassment. But certainly not less embarrassing is the alternative, which seems to be to suppose that land-bridges carried a few little isolated snails across half the

Pacific Ocean, and yet failed to bring Galapagian or Fernandesian creatures into Polynesia, or to bring to the Galapagos any single other fragment of land life from Polynesia. Furthermore, these are but the extremest cases of a world-wide situation, and if the micro-pulmonates can only travel on land, then well-nigh every island on the face of every ocean is an unsubmerged fragment of some previous continental land-bridge.

Land snails, whether large or small, show a very marked discrepancy between their low powers of migration by the ordinary means, and their seemingly extraordinary ability to survive and propagate after undergoing exceptional distant transportation by unusual means. This is particularly true of the little shells, whose powers of spontaneous locomotion are very slight, and whose chances of transportation by wind are reasonably good. Their distribution is consequently very uneven, and their local colonies are liable to develop under conditions of extreme isolation more often than happens with most animals. Thus some species are exaggeratedly local, while others less prone to alteration will range over substantial fractions of the world's available land.

We have already mentioned certain instances of animals that seem to present themselves regularly as exceptions to the limitations of distribution characteristic for their classification. *Succinea*, though far from large, is by no means as small as the Endodontidae, etc., whose distribution it almost emulates, and it exposes a considerable soft surface to boot. Field observations that could explain its wide distribution would be well worth while.

THE COLONIZATION OF VERTEBRATES

Among land vertebrates, the reptiles are emphatically the most successful island immigrants, despite the classical absence of snakes in Ireland. It surely appears that English serpents are less enterprising colonists than their kin elsewhere have been.

Skinks and geckos, but especially geckos, seem endowed with ubiquity, wherever the climate of the respective islands is sufficiently mild. It is frequently hard to tell to what extent ships may have contributed to their distribution, but that chance is definitely excluded for the Galapagian geckos, and apparently for the Bermudian skink. The Hawaiians may have accidentally brought lizards on some of their repeated and systematic voyages. This explanation for Easter Island seems a little surprising, and, repeated again for Marcus Island, it seems like piling up the unexpected—yet there is no direct impossibility, and the lizards are actually there.

Rats and mice constitute another case where it is even more likely that man has played a large but involuntary part. But here again, shipping had nothing to do with the endemic mice of the Galapagos. This may count as the only unequivocal instance of a mammal that has preceded man across an appreciable stretch of ocean.

THE FAUNA OF THE GALAPAGOS ISLANDS

The fauna of the Galapagos Islands (15, 63, 13, 3) is now under process of monographic treatment by the California Academy of Sciences, and it would be presumptuous for us to attempt an extended analysis of the as yet incompletely published results. A few points may nevertheless be indicated.

Among mammals one, or perhaps two, species of neotropical mice (25, 37) that originally found their way to this land, have differentiated along geographical lines, to become five or more species. For

three of the species the special Galapagian genus, *Nesoryzomis*, has been created. An endemic bat has also been found. All other non-pelagic mammals were absent before ships brought them in, or else perished prehistorically, as is known to have been the case on the Falkland Islands.

For reptiles the Galapagos are reported to have been anciently accessible (15, 63, 59, 60). Or at least, this land was successfully reached by one species of giant tortoise, one gecko, one *Tropidurus* lizard, two iguanas, and two snakes. While this is a much better showing than for mammals, and better than one would naturally expect across the present 900 miles of open ocean, it is poorer than should be counted upon if the prolific reptile fauna of Panama had once had untrammeled access over dry land. All of these reptiles seem to have benefited by land connections between islands now separate, but with not over 300 fathoms depth of water between them (3). Since the several islands became separated all of the reptiles except the marine iguana have differentiated into geographical races and species.

The insect list looks fragmentary and for the most part disharmonic, although a considerable proportion of the species are peculiar to the Galapagian area. Among the ants (64), however, there are 4 species that have developed geographical races, to make a total of as many as 26 taxonomically recognized races.

Snails (13, 14) show a highly developed series of 76 named species, in which the predominant element is 53 species, or 66 geographical races, of *Nesiotus*, a subgenus of *Bulimulus*. Their aspect is, in the broad, that of a faunula, moderately abundant, but miscellaneous at the start, and greatly expanded into a new harmonization under the influence of complex geographical relationships. We have already remarked on the presence of a stray form whose generic relations are Polynesian.

Among evolutionists the fame of the Galapagos Islands is derived even more from their birds than from the reptiles, to which they owe their name (15, 17, 18, 54, 55). Modern evolutionary biology came into being with Darwin's study of the 6 endemic avian genera found here, 5 of which are now placed in an essentially endemic Galapagian family. This family, the Geospizidae, seems in the light of modern studies to have been originally a single immigrant stock, later diversified and grown extremely unstable in form of bill and in other characters that are generally depended upon by taxonomists. The generic characters are to a considerable extent adaptations to differing stations and food habits, but the marked differences between lesser geographical races and the large individual fluctuations seem to stand in no relation to food, and not to be greatly subject to natural selection. The usual taxonomic categories are consequently very much blurred, and must be understood only in an approximate sense. On the field (17) they give the impression of a vigorous, flexible stock, not yet weakened by specialization. The only point in which they seem stereotyped is in their nest structure, which is always roofed, with a side entry.

It would appear that these birds have contributed to science one of our finest examples of what happens when an animal has moved out of the closely competitive life on continents and become subject to an island environment that offers a great diversity of alternative opportunities, unhindered by the competition of rival species. Diversification comes to be actually at a premium, as pointed out by J. T. Gulick (21, 20), and even natural selection builds up a tendency toward instability of type.

THE FLORA AND FAUNA OF THE HAWAIIAN ISLANDS

In all the world the richest, maturest, and at the same time one of the most extreme cases of a flora and fauna built entirely out of trans-oceanic waifs is, if the majority opinion is correct, the Hawaiian Island group, located 2,000 miles from North America, more than 3,000 miles from the shores of Japan, and over 1,000 miles from any other biologically significant islands. Unlike the western outriders of this group, to which we have already made reference, these lands have continuously for a long time possessed an exuberant flora which could harbor and nourish a large variety of the smaller forms of animal life. There has been indeed some doubt cast upon the purely oceanic origin of this life, in consequence of the circumstance, as I believe, that the very perfection and antiquity of the processes have rather heavily disguised their earlier stages. These islands have come to be a distinct zoo- and phyto-geographic region of no mean significance. They are inhabited by distinctive genera and families with a bewildering wealth and variety of species, so that it takes close analysis of the lists before one can detect that the present highly harmonized regional picture is built on a foundation of scant and disharmonic beginnings.

Botanists report (23) that after eliminating the Polynesian industrial and food plants there is left a very distinctive and very abundant local list with an extremely high proportion of unique genera in a few families, among which Compositae and Lobelioidae are outstanding. There is a preponderance of plants spread by wind-carried spores and minute seeds. Among the very early arrivals seem to have been representatives of the Lobelioideae (47), probably in part wind-borne and in part strewn by birds. They have developed into a list of 146 species and varieties, all of them endemic, assignable to seven genera, all but one of which are peculiar to the group. Some of them have the proportions of fair sized trees, and the family as a whole contributed much to the general aspect of the luxuriant rain forests. *Vaccinium* presumably represents a definite case of bird transportation rather than wind, with North America as the source. Its presence is most interesting, as the distances involved must be very close to the extreme physiological maximum that land birds can traverse, and still carry fruit seeds in their droppings. It rouses curiosity as to what may still be found in the intestines of the golden plover at the time of its arrival in Hawaii twice each year, on the road between Alaska and Tahiti.

It is conspicuous that although this land is climatically eminently adapted for palms, there is only one genus, *Pritchardia*, found there outside of the cocoanut and the more recent importations. All the species are endemic, but the genus has been reported also from South Pacific islands and the south-western part of the United States. Its mode of introduction to these islands is problematical. It has been suggested that this might possibly be another example of avian transportation (23), although one must concede that a ripe seed of any present Hawaiian species would be a formidable morsel for any carrier bird that seems easily available today.

Among animals, the most notable features are the snails, the beetles, and the land birds. The Hawaiian Islands are the exclusive home of at least one entire family in each of these animal classes, and each of these endemic families is represented by numerous and diversified species.

A modern check list of land snails (9) indicates about 970 species and geographical races, all but a negligible few being endemic—certainly a list worthy of a fair-

sized continent! Still more striking is the fact that 417 of these belong to a distinctive family, the Amastridae, which apparently originated locally, and in all probability from the common ancestry of a single importation, and that 192 more represent another family, the Achatinellidae, even more restricted, as it occupies only a portion of the island group. Furthermore, it is rather more probable than otherwise that the Achatinellidae were derived locally from Amastridae, since they resemble the Amastridae rather more than they do any other family from which descent might be suspected. Within these families are genera ranging from trivial micro-fauna to turreted shells three inches long, from oviparous denizens of semi-arid rock plains to viviparous dwellers in the high branches of the perpetually humid rain forest. The dentition of the radula, a feature upon which systematists place great dependence, ranges from the bluntly several-cusped forms of the rougher ground-feeders to the slender sets of needles that transform the radula of most of the tree-dwellers into a sort of delicate combing instrument for gathering the gritless algal growth on the moist bark of trees.

The adequate description of these snails requires ponderous volumes (46, 22, 20). We must be satisfied here with a few considerations. It is evident that the vast diversification is proof of the great local antiquity of these families, and hence of a considerable geological antiquity of their island habitat. It also shows absence of serious enemies or competitors, and an adaptive evolution in manifold directions to fit many different local environments. In addition there is the obvious influence of geographical isolation into numerous colonies separated from each other by the features of a sharply developed topography.

In the face of such antiquity the question of origin very nearly removes itself from discussion. It ceases to be necessary to hypothecate an immigration of large snails, as there is not the least evidence that the original forms may not all have been minute. Whether their ancestors came from a stock that has left other descendants in other parts of the world is also unanswerable, because if they have, they and their cousins in other world regions must apparently have diverged considerably from each other. Paleontology can contribute almost nothing to the genealogical tree of these Pulmonate families, whose significant distinctions lie entirely in the soft parts that never fossilize.

About all we can say positively is that the ancestral snails did not walk across on any continuous land-bridge, for we find that these slowest of all pedestrians are the only conspicuous group of wingless land animals that have made this island kingdom their own since long ago. Hawaii's one species of rat and half a dozen or so forms of lizards (which are its only land vertebrates other than birds and bats) contribute nothing to a land-bridge hypothesis, because the lizards are all modern species originating in Polynesia, and the same may easily be supposed for the rat. It is true that this identical rodent has not been reported from elsewhere, but it is only difficultly distinguished from some of the Malayan and Polynesian races (34½), and many of the facts regarding Polynesian rats have been lost for all time through the destructive aggressions of ship rats.

As an evolutionary phenomenon, this land snail fauna is strictly in line with the land snails of Bermuda or of St. Helena, only that the process has gone further apparently on a longer time allowance, and in a far more complex geographical setting.

The history of Hawaiian land birds (66, 63, 51, 6, 26, 29, 8) must have begun with

the arrival of some form of tropical American honey creeper, which became in due time the progenitor of all the 18 genera and 40 species of the Drepanididae. These inhabited the whole Hawaiian group, and also reached Laysan, 800 miles farther west. Seemingly somewhat later, but certainly very long ago, came the ancestors of the two Hawaiian genera of Old World honey eaters, a rail, a thrush, and an old world flycatcher. Each of these evolved to be generically distinct, the rail meanwhile losing its power of flight. The Laysan honey-eater is a drepanid, of secondary

It seems, then, that successful and permanent species introductions of land birds have occurred in this region not less than 9 times, and not over 11 times, in the total history of the group. Some six or seven of these were of passerine birds, whereby 6 passerine families have become established. One of these is limited, however, to Laysan, making only five passerine families in the Hawaiian Islands proper. Most of them are related to tropical types and not to the typical seasonal migrants of the temperate zone, and it is therefore natural to infer that they represent waifs rather

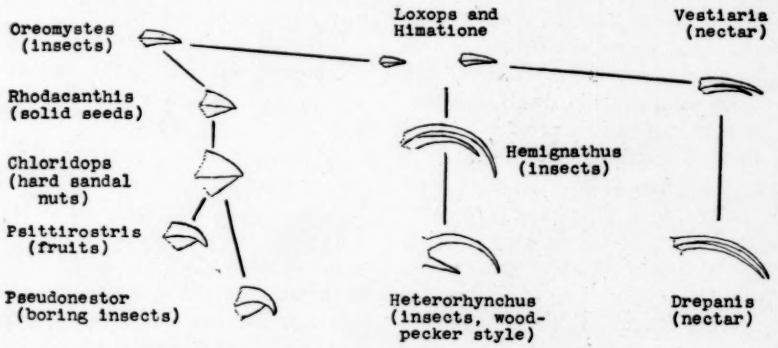

FIG. 1. DIAGRAM OF THE MORE IMPORTANT DREPANIDIDAE

Indicating the food eaten and the corresponding forms of bills. In the main each genus of these birds has a distinctive species on each of the Hawaiian Islands.

Hawaiian derivation, but the rail is referable to its own unique genus, and may have a separate origin. The Laysan miller bird definitely represents one more separate colonization, this time by an Old World warbler.

Two land birds, a hawk and a crow, are referable to North American genera. Either they have arrived so recently, or else cross-breeding with later arrivals has so retarded their differentiation, that they merely count as specifically distinct. Similarly, the Hawaiian owl is as yet only varietally distinguishable from a widespread American species.

than stranded colonies of migratory birds. If there is any truth in the theory of Guppy (23) that the mid-Pacific islands were part of an ancient seasonal bird route, it must apply to water fowl and shore birds rather than the passerine families.

When the ancestral pair of drepanids first arrived, and found this land rich with beetles and various other insects, and gay all the year around with lobelias and other honey-bearing flowers, yet with no rival or enemy in sight, it had before it an evolutionary opportunity such as can scarcely have been duplicated in the whole history of avain life. The standardizing ef-

fect of close natural selection was removed. Food was very abundant but probably differed in one way or another from what those birds had formerly been used to, so that they may even from the start have begun to turn aside from their previous habits of feeding. And when pressure of population finally began, there came to be a direct premium on physical variability, and on versatility of feeding. In addition they were subjected to considerable geographical isolation as between the several islands. This must have led over into a condition comparable to that found today among the Geospizidae of the Galapagos,—several new-formed genera, all of them very variable and rather versatile feeders, but each with a norm for beak, claws, etc., corresponding fairly well to its major tendencies in food and habits. These several genera must have spread, each independently, over all the islands that furnished the appropriate foods, and each developed its own geographically restricted races and species. But in Hawaii all this happened ages ago, and since that time constant competition and selection and specialization have worked the extreme results which the accompanying diagram visualizes. The ancestrally homogeneous family now has its 18 genera ranging from stocky, seed-eating birds with bills like grossbeaks and parrots, through finch-like birds that glean smaller seeds, to little creatures with long, thin, flexible bills for gathering honey and insects out of tubular lobelias, and even birds with a short, stout lower mandible and a very long, slender upper one, the first usable for pecking away loose bark, and the other for probing out the grubs of the native boring beetles. Adaptation has become completely and narrowly specialized for feeding upon the nectar, seeds, and insects native to their Hawaii. And by the same token, all but a few of them are now ready to pay the penalty of over-specialization in a restricted environment. Such as are not exterminated by enemy pests like the mongoose, that they know not how to evade, are doomed to disappear whenever cattle destroy the particular environmental combination on which they depend. The Hawaiian woodlands, alive with song in 1850, are today already largely silent, except to some degree on the single island of Hawaii, where the destructive forces seem to have moved a little less rapidly.

The Hawaiian Islands carry the unusual distinction, among remote insular regions, of having fresh-water fishes (8) in their brooks. They belong to the gobies, a group characteristic of the East Indies and of Oceania, and showing considerable power of adaptation to salt, brackish, and fresh water. Hawaiian fresh water gobies are peculiar in the possession of specially modified fins, by which they are able to cling to rock surfaces in a rushing brook.

FAUNA OF GREATER OCEANIA

It is very doubtful what the geography of Polynesia and Micronesia was like during Mesozoic and Tertiary times. The ocean bottom in these areas is thrown into ridges and troughs trending mostly northwest and southeast. On top of the ridges are most of the volcanic cones which result in islands. Aside from these cones, the whole region taken in the broad would count as deep water. In fact, any part of the ocean where the proportionate area of fairly deep sea falls as low as 98 per cent, and the area above water becomes as great as 0.2 per cent is treated by geographers as dense archipelago. It is geologically unlikely, therefore, that this vast area could ever have been actually continuous land, as that would involve a considerable alteration in the isostatic balance of a whole

major region of the world, although faunistic arguments favoring such a supposition have been brought forward by Von Ihering (28), Baur (3), Hutton (27), and others. The distribution of various forms of life, and more especially of the land-snail genus, *Partula*, seem at least to demand that land areas must have been much larger, and much less discontinuous in the past than they are now. And this much would indeed be possible within the limits set by geological considerations.

This hypothetical bigger and better Oceania was sufficiently continuous to be open to colonization by frogs as far out as the Fiji Islands (23, 3, 2), but not beyond. East and north of this point there are no land reptiles except certain small lizards, no native mammals except rats and bats, and no amphibia at all.

The Oceanian snail fauna (43) is strong in Endodontidae, Pupillidae, Succinidae, and rather primitive forms of Zonitidae. These are fairly cosmopolitan groups representing in their soft anatomy a relatively archaic assortment of land snails. Similarly archaic in type are the more distinctively Oceanian Tornatellinidae and the genus *Partula*. Thus as a repository of primitive forms, it has been argued that Oceania does for the world of Pulmonate snails more or less what Australia does for the world of mammals.

The genus *Partula*, found widely throughout the volcanic islands of Micronesia and Polynesia, but never on the less humid, low atolls, is responsible in large measure for the theory of more extensive lands in these regions (43). Its 120 geographically restricted species mostly weigh too much and are too tender to fit easily into theories of transport by air or by sea. Yet forms looked upon as congeneric are reported over all the distance from Guam to the Marquesas, a dispersal far in excess of 5,000 miles.

Charles Hedley has suggested in a letter quoted by Pilsbry (43, see also 24), that if we can suppose that the alignment of submarine ranges extending more than 3,000 miles from the Marshall Islands southeastward to the Austral group was formerly united into a fairly continuous ridge of land, it would explain many of the difficulties in the wide dispersal and harmoniousness of the forms of life of the mid-Pacific. The Hawaiian analogy would indicate the type of insular life which such a major island could develop without ever making contact with any continental area. It would then be necessary to hypothecate a later series of connections that would spread this fauna as far as the Marquesas Islands on one side and the Carolines and Ladrones on the other side, while the Fiji group would be supplied partly from this source and partly from Melanesia. For the present such a set of postulates can only be speculative; yet the principles brought out by the Hawaiian data may guide us eventually toward a rational crystallization of this or any other hypothesis that shall explain the wide-spread harmony in the otherwise strictly insular fauna of Polynesia.

CONTINENTAL OUTRIDERS

We have concerned ourselves thus far with regions that were *a priori* likely to give evidence against previous continental connections. By way of contrast, the islands of the South Indian Ocean could be mentioned (50),—Kerguelen, Crozett, St. Paul, and two or three more. In sheer mileage they are remote enough to be as oceanic as any. They are not even near to each other. But the regions between them and to the southward lack the deepness of typical ocean, and one of those islands, Kerguelen, displays sedimentary rocks and coal measures which suggest continental conditions. They have many plants and

insects in common with each other, notable among them the Kerguelen cabbage, or antiscorbutic cabbage, and a wingless fly that feeds upon it. Both of these are described as ill fitted for any form of inter-island dispersal, and on evidence of this nature it is surmised that these land fragments are the last remains of an extensive territory, possibly a northward lobe of the Antarctic continent. One or two plants that are shared by these lands in common with Tristan da Cunha in the South Atlantic become explicable if their original home was a milder Antarctica.

Falkland is interesting as a region which, beginning as continental, has lost part of its animals by extinction, and so has come to simulate somewhat the fragmentary oceanic faunal type. A species of coyote formerly found there seems to have exterminated its prey and then itself perished, with the result that a small mouse is the only surviving mammal. This warns us of a possibility that ancient continental out-riders may fail to be recognized as such. The true relationship is still shown here by tender South American invertebrates, such as the earthworms (33).

AGENCIES OF TRANSPORTATION

Our review has, we believe, made it obvious that the more recent accessions of faunistic information tend mostly to sustain the pure oceanic character of prehuman life on a considerable number of remotely situated islands. It has been possible to start with midoceanic islets carrying floras and faunas so fragmentary and so palpably young, geologically speaking, that no credence can be given to any theory that demands a land bridge for them. Through their lists of species we have been able to verify the ability of certain rather restricted types of organisms to suffer transportation into such distant spots by rare and rather accidental means. What agency is responsible in the several specific instances remains problematical as a rule, and we are reminded by occasional paradoxes of distribution that the problem is not by any means adequately covered by the hypotheses thus far worked out. Nevertheless, the general aspect of the findings favors a major emphasis upon transportation by windstorm or at least over the air, and a minor emphasis upon transportation by driftwood and flotsam. Not a few plant seeds and some small invertebrates are presumably carried by migrant birds.

Turning next to islands with a longer geological history, it has been possible to show a series of examples possessing well developed lists of inhabitants, limited nevertheless to such plants and animals as can readily be derived by descent from the types of creatures that find their way without the aid of land bridges. This analysis has given particularly striking results for St. Helena and the Hawaiian Islands, while the case of Bermuda is modified by the lesser degree of remoteness.

INSULAR EVOLUTION

Far distant islands serve as an especial test for the efficiency of the evolutionary processes in creating new adaptations. They are seeded with plants, and then supplied with a few insects, birds, and bats, and a few wind-waifs and drift-wood waifs of small, hardy creatures. Their shores are littered with sea animals of all descriptions, various of which might theoretically crawl out and take possession of a terrestrial realm. There is thus presented a great opportunity for some radically new evolutionary departure. Do we find any? Only in a most limited measure. Really radical new departures seem to require a longer time allowance than these geologically not very permanent islands can furnish. A rail may forget its wings

and become definitely terrestrial; a microsnail may blossom out and appear like a big helix; a bird may take up new food habits and undergo great alterations of bill character; but nowhere has any sea creature snatched the opportunity to evolve into a new land animal. Even marine turtles, which visit the beaches to lay their eggs, have not reverted to life on land. But the older the isolated region, the more nearly it escapes from this criticism. On Hawaii, where apparently the time factor has been least limited, and where insular life has worked out its own destiny perhaps more completely than in any other location, we find the nearest approach to the creation of genuine novelties,—birds that have a truly original equipment for extracting wood-boring grubs, and brook fishes possessed of sucker-like fins.

The question whether creatures that have been transformed through insular isolation have ever come back as triumphant new biological successes, able to modify the major stream of continental evolution, has not yet found any clear answer. Present day evidence has to be inferential, and the fossil records are rarely, if ever, detailed enough to give evidence on this question. Students of the Galapagos birds judge that the Geospizidae are today a vigorous stock (17), flexible as well as novel in its adaptations, and presumptively as fit as other bird-groups to face competition and climatic changes. From this we might argue that existence on an island, if not too prolonged, need not unfit a stock for the contest for survival in a heavily populated continent.

It is worth noting that both horticulturalists and animal fanciers have been pleased with various of the world's island products, such as the Bermuda fern, St. Helena violet, Canary finch, and the like. Yet, after all, the contribution of domesticated plants and animals made by oceanic islands is relatively slight by comparison with the great yield from continental islands like Japan, Madagascar, or the East Indian groups. Even in the oceanic zone, those native plants that are ecologically predominant or outstanding from the human utilitarian view-point are largely the ones whose powers of dispersal—like the cocoanut—render them least drastically isolated in a remote insular location. Although this picture is too complex to prove the point, it harmonizes with the suspicion that geographic isolation, if it becomes too drastic and too prolonged, will cease to aid the main current of evolutionary progress.

The topic of insular evolution should not be left without a mention of the circumstance that sucessful breeds of domestic animals have been developed in a large number of instances in such locations as the Isle of Man, Malta, Jersey, Guernsey, and the Friesian islets. The cattle on these North Sea and Channel islands may fairly be claimed as a positive evolutionary advance in adaptation to the human element of the environment.

In the broad, the general picture of evolution that we have observed under rigorous oceanic isolation is filled with an extraordinary wealth of varietal and species characters devoid of serious adaptive significance, together with a fair display of not too radical novelties of adaptation. Indeed, if we can apply what we see here to an appraisal of evolution elsewhere, we must conclude that the developmental scene is filled chiefly with a rich by-play of all manner of non-utilitarian divergences, while only here and there some truly progressive, permanently significant innovation may come into existence.

LIST OF LITERATURE

(1) Aurivillius, Chr. 1931. Coleoptera-Curculionidae von Juan Fernandez und der Oster-Insel. Skottsberg, Carl, and others:—The Natural History of Juan Fernandez and Easter Island. Uppsala (1920–1931), Vol. III, p. 461–477.

(2) Barbour, Thomas. 1923. The frogs on the Fiji Islands. Proc. Acad. of Nat. Sci. of Phila., Vol. LXXV, p. 111–115.

(3) Baur, G. 1897. New observations on the origin of the Galapagos Islands. Amer. Naturalist, Vol. XXXI, p. 661–680.

(4) Berland, Lucien. 1924. Araignées de l'île de Paques et des îles Juan Fernandez. Skottsberg, Carl, and others:—The Natural History of Juan Fernandez and Easter Island. Uppsala (1920–1931), Vol. III, p. 403–415.

(5) Bryan, E. H., Jr. 1926. Insects of Hawaii, Johnston Island, and Wake Island. Bernice Pauahi Bishop Museum Bulletin, No. 31, 94 pp., 9 figs.

(6) Bryan, William A. 1901. Key to the Birds of the Hawaiian Islands. Bernice Pauahi Bishop Museum Memoirs, Vol. I, p. 257–332, Plates 16–30.

(7) ———. 1903. Monograph of Marcus Island. Bernice Pauahi Bishop Museum, Occasional Papers, Vol. II, No. I, p. 77–139.

(8) ———. 1915. Natural History of the Hawaiian Islands. Hawaiian Gazette Co. 596 pp.

(9) Caum, E. L. 1928. Check List of Hawaiian Land and Fresh Water Mollusca. Bernice Pauahi Bishop Museum Bulletin, No. 56, Honolulu, p. 1–79.

(10) Christopherson, Erling. 1927. Vegetation of Pacific Equatorial Islands. Bernice Pauahi Bishop Museum Bulletin No. 44, Honolulu.

(11) Chopard, L. 1924. Grillidae de Juan Fernandez et de l'île de Paques. Skottsberg, Carl, and others: The Natural History of Juan Fernandez and Easter Island. Uppsala (1920–1931). Vol. III, p. 321–323.

(12) Churchill, Wm. 1912. Easter Island. Carnegie ublication No. 174, 340 pp.

(13) Dall, Wm. H. 1896. Insular land shell faunas. Proc. Acad. of Nat. Sci. Phil., 1896, p. 395–451, Plates 15–17.

(14) Dall, Wm. H., and Ochsner, W. H. 1928. Landshells of the Galapagos Islands. Proc. Calif. Acad. of Sciences, 4th Ser., Vol. XVII, p. 141–184, Pl. VIII, IX.

(15) Darwin, Charles. 1840. Voyage of the Beagle. London. 615 pp. i.e. Journal of Researches into the Geology and Natural History of Various Countries Visited by H. M. S. Beagle.

(16) Ebsen-Petersen. 1924. More Neuroptera from Juan Fernandez and Easter Island. Skottsberg, Carl, and others: The Natural History of Juan Fernandez and Easter Island. Uppsala (1920–1931), Vol. III, p. 309–313.

(17) Gifford, E. W. 1919. Field notes on the land birds of the Galapagos Islands, and of Cocos Island, Costa Rica. Proc. Calif. Acad. of Sciences, Vol. II, pt. 2, p. 189–258.

(18) ———. 1926. The birds of the Galapagos Islands. Proc. Calif. Acad. of Sciences. Vol. II, pt. 3, p. 1–132, pl. I—VII.

(19) Gulick, Addison. 1904. The fossil land snails of Bermuda. Proc. Acad. of Nat. Sci. Phila. Vol. LVI, pp. 406–425.

(20) ———. 1932. Evolutionist and Missionary, John Thomas Gulick. University of Chicago Press, 556 pp.

(21) Gulick, John T. 1872. On diversity of evolution under one set of external conditions. Linnean Soc. Jour. Zool., Vol. XI, pp. 496–505.

(22) ———. 1905. Evolution Racial and Habitudinal. Carnegie Institution Publication No. 25. 269 pp.

(23) Guppy, H. B. 1906. Observations of a Naturalist in the Pacific between 1896 and 1902. Vol. II. Plant-Dispersal. Macmillan, London. 627 pp.

(24) Hedley, Charles. 1899. A zoogeographic scheme for the mid-Pacific. Proc. Linnean Soc. of New South Wales, Vol. XXIV, pp. 391–417.

(25) Heller, Edmund. 1904. Mammals of the Galapagos Archipelago, exclusive of the Cetacea. Proc. Calif. Acad. of Sciences, 3rd. Ser., Vol. III, p. 233–250, Pl. XXIII–XXIV.

(26) Henshaw, H. W. 1903. Birds of the Hawaiian Possessions. Honolulu.

(27) Hutton, F. W. 1896. Theoretical explanation of the distribution of southern faunas. Proc. Linnean Soc. of New South Wales, Vol. XXI, pp. 36–47; abstract in Ann. of Nat. Hist., XVIII, p. 120, 1896.

(28) Ihering, H. von. 1892. On the ancient relations between New Zealand and South America. Trans. New Zealand Institute, Vol. XXIV, p. 431–445.

(29) Jordan, David Starr. 1905. Origin of species through isolation. Science, n.s., Vol. XXII, p. 545–562. Nov. 3, 1905.

(30) KNOCHE, W. 1919. Ueber die Kulturpflanzen der Osterinsel. Ztsch. d. deutsch. wiss. Vereins zur Kultur und Landkunde Argentiniens, 1919, Heft 3 (24 pp.).

(31) ———. 1921. Die Osterinsel. Verh. d. deutsch. wiss. Vereins in Santiago. Vol. VII, p. 3–61.

(32) MEINICKE, CARL E. 1876. Die Inseln des stillen Oceans. Pt. II, p. 228–235.

(33) MICHAELSEN, W. 1903. Die geographische Verbreitung der Oligochaeten. Berlin, 186 pp.

(34) ———. 1921. Oligochaeten von Juan Fernandez und der Oster-Insel. Skottsberg, Carl, and others:—The Natural History of Juan Fernandez and Easter Island. Uppsala (1920–1931), Vol. III, p. 31–32.

(34½) MILLER, GERRIT S., JR. 1924. The Characters and Probable History of the Hawaiian Rat. Bernice Pauahi Bishop Museum Bulletin No. 14. 11 pp.

(35) NAVÁS, LONGIN. 1921. Nevropteres des îles Juan Fernandez et de l'île de Paques. Skottsberg, Carl, and others:— The Natural History of Juan Fernandez and Easter Island. Uppsala (1920–1931). Vol. III, p. 125–128.

(36) ODHNER, NILS H. 1922. Mollusca from Juan Fernandez and Easter Island. Skottsberg, Carl, and others: The Natural History of Juan Fernandez and Easter Island. Uppsala (1920–1931). Vol. III, p. 219–253.

(37) OSGOOD, WILFRED H. 1929. A new rodent from the Galapagos Islands. Pub. of the Field Mus. of Nat. Hist., Zool. Ser., Vol. XVII, p. 16.

(38) PEILE, A. J. 1924. Notes on the genus *Poecilozonites*. Proc. Malacol Soc., Vol. XVI, pt. 1, pp. 17–21.

(39) —. 1925. Further notes on the genus *Poecilozonites*. Proc. Malacol Soc., Vol. XVI, pt. 5, pp. 257–258.

(40) —. 1926. The mollusca of Bermuda. Proc. Malacol Soc., Vol. XVII, pt. 2 & 3, pp. 71–98.

(41) PILSBRY, H. A. 1888. On the helicoid land mollusks of Bermuda. Proc. Acad. of Nat. Sci. Phila., 1888, p. 285–291.

(42) —. 1893. Manual of Conchology. Ser. 2, Vol. IX, p. 28.

(43) —. 1900. The genesis of mid-Pacific faunas. Proc. Acad. Nat. Sci. Phila., pp. 568–581.

(44) —. 1906. Manual of Conchology, Ser. 2, Vol. XVIII, p. 217–218, Pl. XI, fig. 10, 11.

(45) —. 1924. Recent and fossil Bermudian snails of the Genus *Poecilozonites*. Proc. Acad. of Nat. Sci. Phila., Vol. LXXVI, pp. 1–9.

(46) PILSBRY, H. A., and COOKE, C. M. 1910–1916. Manual of Conchology, Ser. 2, Pulmonata, Vol. XXI-XXIII.

(47) ROCK, JOSEPH F. 1919. A monographic study of the Hawaiian Species of the Tribe Lobelioideae Family Campanulaceae. Mem. Bernice Pauahi Bishop Museum, Vol. VII, 393 pp., 217 plates.

(48) ROMANES, G. J. 1897. Darwin and After Darwin, Vol. III, 168 pp.

(49) SAYLES, R. W. 1931. Bermuda during the Ice Age. Proc. Amer. Acad. of Arts and Sci., Vol. LXVI, pp. 381–468.

(50) SCHENCK, HEINRICH. 1905. Vergleichende Darstellung der Pflanzengeographie der subantarktischen Inseln. Wissenschaftliche Ergebnisse der deutschen Tiefsee-Expedition auf dem Dampfer Valdivia, 1898–1899. Vol. II. Pt. 1, p. 1–178, Pl. I-XI. Gustav Fischer, Jena.

(51) SHARP, DAVID, and collaborators. 1899–1913. Fauna hawaiiensis, Cambridge, England.

(52) SKOTTSBERG, CARL. 1922. Catalogue of Easter Island Phanerogams. Skottsberg, Carl, and others: The Natural History of Juan Fernandez and Easter Island. Uppsala, (1920–1931), Vol. II, p. 59–83.

(53) SMITH, E. A. 1892. Land shells of St. Helena. Proc. Zool. Soc., 1892, pp. 258–270.

(54) SNODGRASS, ROBERT EVANS, and HELLER, EDMUND. 1904. Papers from the Hopkins—Stanford Galapagos Expedition, 1898–9. XVI. Birds. Proc. Wash. Acad. of Sci., Vol. V, p. 231–372.

(55) SWARTH, HARRY S. 1931. The Avifauna of the Galapagos Islands. Calif. Acad. of Sci., Occasional Papers, XVIII, 299 pp.

(56) VANATTA, E. G. 1910. Bermuda shells. Proc. Acad. of Nat. Sci. Phila., Vol. LXII, pp. 664–672.

(57) —. 1924. Land shells of Admiral's Cave, Bermuda. Nautilus (Phila.) Vol. XXXVIII, pp. 6–7.

(58) —. 1924. Four new species of shells. Proc. Acad. of Nat. Sci. Phila., Vol. LXXVI, pp. 423–425.

(59) VAN DENBURGH, JOHN. 1912. The snakes of the Galapagos Islands. Proc. Calif. Acad. of Sciences, 4th Ser., Vol. I, p. 323–356, Pl. XXIV-XXX.

(60) —. 1914. The gigantic land tortoises of the Galapagos Archipelago. Proc. Calif. Acad. of Sciences, 4th Ser., Vol. II, Pt. 1, p. 203–374, Pl. XII-CXXIV.

(61) VERHOEFF, KARL W. 1924. Ueber Myriapoden

von Juan Fernandez und der Osterinsel. Skottsberg, Carl, and others: The Natural History of Juan Fernandez and Easter Island. Uppsala, (1920–1931), Vol. III, p. 403–415.

(62) Verrill, A. E. 1902–03, & 1907. The Bermuda Islands. Trans. Conn. Acad. of Sci. and Arts, Vol. XI, pp. 413–956, pl. LXV–CIV; Vol. XII, pp. 45–348, pl. XVI–XXVII.

(63) Wallace, Alfred Russel. 1897. Island Life. 2nd edition.

(64) Wheeler, William Morton. 1919. The ants of the Galapagos Islands. Proc. Calif. Acad. of Sciences, 4th Ser., Vol. II, Part II, p. 259–297.

(65) Wheeler, William Morton. 1924. Formicidae from Easter Island and Juan Fernandez. Skottsberg, Carl, and others: The Natural History of Juan Fernandez and Easter Island. Uppsala (1920–1931), Vol. III, p. 317–319.

(66) Wilson, S. B., and Evens, A. H. 1890–99. Aves Hawaiienses, London.

(67) Wollaston, T. V. 1877. Coleoptera Sanctae Helenae, London, 256 pp.

(68) Zimmerman, A. 1924. Coleoptera—Dytiscidae von Juan Fernandez und der Oster-Insel. Skottsberg, Carl, and others: The Natural History of Juan Fernandez and Easter Island. Uppsala (1920–1931), Vol. III, p. 299–304.

TEMPERATURE RELATIONS OF SEED GERMINATION

By THOMAS I. EDWARDS

Department of Biology, School of Hygiene and Public Health, The Johns Hopkins University

[*Botanical Contribution No. 118 from the Laboratory of Plant Physiology, The Johns Hopkins University*]

INTRODUCTION: TWO CYCLES OF PUBLICATIONS

THE literature on the temperature relations of seed germination extends throughout about a century and a third and may be considered as of two cycles: from 1860 to 1878 and from 1904 to the present. Precise study of these relations could not begin, of course, until after the invention of the thermometer, and a good many years elapsed after its invention before that instrument found use in seed-germination studies. During the nineteenth century there were two main reasons for studying this subject; one was the purely utilitarian problem of learning how to make crops grow better, but every worker considered his results in relation to the problem of plant distribution. Certain kinds of plants were known to be naturally restricted to tropical regions, for instance; was this due to the necessity for high temperatures during germination? Conversely, were plants of the temperate zones prevented from growing in the tropics because of high temperatures? Seed-germination studies seemed to promise valuable evidence on these and other ecological questions, which undoubtedly provided a powerful stimulus for studies of this kind. Automatically controlled temperatures were not available and workers utilized selected locations in cellars and greenhouses, where temperature fluctuation was slight, to provide the lower temperatures they needed. For higher temperatures pots of soil or metal chambers were heated by means of small oil flames, the distance of the flame below the vessel being chosen so as to give the required temperature.

Lefébure (38) published on this subject in 1801 and Edwards and Colin's paper (15) appeared in 1834. Sachs's (48) clear discussion of the general temperature relations of seed germination, which was published in 1860, seems to have aroused considerable interest in this subject. Alphonse de Candolle (10), who may have been somewhat influenced by Sachs, published in 1865. In 1874 and 1875 Friedrich Haberlandt (25, 26) contributed two important papers, which were so thoroughly and carefully executed that they appear to have removed the incentive for further work in this field until about the end of the nineteenth century. At about the same time as Haberlandt's work (namely in 1870 and 1878) there appeared two papers by de Vries (11) and by Oudemans and de Vries (46). That some kinds of seeds may germinate at the temperature of melting ice was shown at about this time by Uloth (52), whose papers were published in 1871 and 1875, as well as by de Candolle (10) and Haberlandt (27), in 1865 and 1875, respectively. The short period characterized by the work of Sachs, de Candolle, de Vries, Haberlandt and Oudemans and de Vries may be considered as ending in 1878 and there followed twenty years without important publications on this topic.

A new cycle of activity in the study of seed germination as related to temperature opened about the beginning of the present century and has continued to the present, with an accelerated increase in the frequency of contributions. By this time a new situation had arisen, with new motives for studies of this kind. For one thing, there was a growing interest in physiological temperature relations in general, and tests on seeds afforded a means for studying optimal temperatures and for inquiring into their significance. Interest in the 10-degree temperature coefficient (Q_{10}) prompted several studies on germinating seeds. For practical purposes it became desirable to know the most satisfactory temperatures for carrying out seed viability tests. Interest in such problems as those of after-ripening and light sensitivity led several workers to study temperature influence on germination. On the whole, the ecological aspects of germination studies seem to have been lost sight of, and it appears that the work of this cycle is largely independent of that of the first, for only a few of the twentieth-century authors give much attention to accounts published in the first cycle.

Some features of the trends just discussed are brought out by the following tabulation of the numbers of papers on this subject that appeared in successive five-year periods.

PERIOD	NUMBER OF PAPERS	PERIOD	NUMBER OF PAPERS	PERIOD	NUMBER OF PAPERS
1860–64	1	1885–89	—	1910–14	3
1865–69	1	1890–94	—	1915–19	2
1870–74	2	1895–99	—	1920–24	8
1875–79	2	1900–04	1	1925–29	19
1880–84	—	1905–09	2	1930–	5

In this table the two cycles of publication stand out clearly with a 26-year interval between them. There is a remarkable regularity of increase in the second cycle, especially when it is realized that the literature on this subject is so scattered that few workers are able to cite more than four or five papers dealing with the temperature relations of seed germination. The peak of publication appears to fall in the period 1925–29, more specifically in the two-year period 1928–1929, and articles are now appearing at a slower rate. A careful search of many bibliographic indexes and abstracting journals has failed to show any important papers on seed germination published in the interim between 1880 and 1900, and later writers on this subject do not cite any important contributions that appeared in that period. Fashion turned away from this kind of seed germination study about 1880 and did not return till after 1900. Such changes of fashion in botanical research have recently been discussed in an interesting way by Stevens (50).

The following sections present a review of the literature on the temperature relations of seed germination as shown by experiments in which maintained temperatures were employed. The subject of temperature fluctuation or alternation, specific effects of which have been reported for a number of kinds of seed, is not included in this review. Another special subject not taken up here deals with the after-ripening of seeds and the causes of delayed germination. There is a considerable literature on each of these aspects of seed germination.

This review was prepared in connection with an experimental study of the influence of maintained temperatures on the germination of a lot of soybean seed (14), carried out at the Laboratory of Plant Physiology of the Johns Hopkins University, and the writer has had the benefit of critical suggestions and editorial help

from Professor Burton E. Livingston, of that laboratory.

LITERATURE OF THE EARLIER CYCLE

Some of the earlier papers on temperature and seed germination that seem to be most important are briefly reviewed in chronological order in the following paragraphs. In 1801 E. A. Lefébure, of Strasbourg, published (38) a book on the germination of radish seed. His work was remarkably thorough and included most of the lines of study that are being followed today in the investigation of seed germination, including the incubation of seeds at a number of approximately maintained temperatures. Lefébure's seeds were killed by exposure to 40°–45° C. and at 36°–38° only one out of 30 seeds germinated but the others were uninjured. At 32°–34° the greater part of the sample began to germinate within 72 hours; at 28°–30° germination was still more rapid and at 22°–25° about 48 hours of incubation was usually required. For temperatures between 12° and 25° little difference in time of germination was noted, these tests being made out-of-doors at suitable times. At 7°–8° germination was slow and at 5°–6° no seedlings were found after 5 days. When seeds were incubated under water the temperature relations were essentially like those just outlined, but longer incubation periods were necessary when water was used.

Lefébure supposed that "caloric" was a specific stimulant for organized bodies; below a certain intensity (8°) it was impotent to stimulate the embryo; from 8° to 38° it was effective, but still greater intensities were injurious. An early concept of physics, which has since been abandoned, and a terminology developed subsequently are the only features that render Lefébure's way of thinking seriously different from ours at the present time.

As early as 1834 W. F. Edwards and M. Colin (15) published a paper in which they set forth some important generalizations that still hold. Their numerical data are fragmentary and their technique would hardly be employed now without considerable modification, but they showed a remarkably clear appreciation of the temperature relations of germinating seeds. They said, for example, that

> . . . . la germination doit s'accélérer avec l'accroissement de la chaleur; mais d'abord les différences dans les vitesses de germination de 10° en 10° de température ne sont pas aussi grandes que l'on pourrait le croire. Et en second lieu, il se passe un phénomène remarquable lorsque la température se rapproche de la limite supérieure. Les graines qui jusqu'alors avaient germé plus vite à mesure que la température était plus élevée, non-seulement s'arrêtent dans cette progression, mais encore rétrogradent; c'est-à-dire qu'aux plus hautes températures où elles peuvent germer, leur germination éprouve un retard considérable.

In 1860 Sachs (48) published an account of a study in which he germinated seeds of corn, wheat, barley, cucumber and scarlet-runner bean in soil at several different temperatures—which were not maintained very exactly—and gauged the efficiency of the temperature by the length of root or shoot produced in 48 hours. His discussion is specially valuable. He defined minimal, optimal, and maximal temperatures for the first time and called attention to the fact that the minimal temperature is generally farther removed from the optimum than is the maximum.

Alphonse de Candolle (10) gave special attention to the time relations of seed germination at different and more or less well maintained temperatures between about 0° and about 50°–57°. He experimented with seeds of 12 species, germinating small samples (usually from 10 to 30 seeds) in moist sand. For each species the time required for the appearance of the first seedling was shorter as successively higher temperatures were examined. At

28°, however, several kinds of seeds required a longer time to germinate than at 24°. De Candolle chose the time required for the appearance of the first seedling in a sample as a criterion for evaluating the influence of temperature on germination, but he recognized that there was much variation in this time requirement.

In 1870 de Vries (11) repeated Sachs's experiments, using a wider range of maintained temperatures and more kinds of seeds. Sachs's experiments were also repeated by Friedrich Haberlandt (25, 26) whose very important reports appeared in 1874 and 1875. In tests that included the seeds of about 70 agricultural plants he found that the seeds of most of the forms tested gave high germination percentages at 19°, 25° and 31°, but that some kinds of seeds showed low germination percentages at higher temperatures. Several kinds gave some germination at 44° but no germination was observed at 50°. In order to specify which of the temperatures tested were most favorable for germination Haberlandt found it necessary to examine the time relations of germination. Taking as a basis the incubation time elapsing before the appearance of the first seedling in any culture, he found that high and low temperatures retarded germination and an intermediate range of temperature permitted germination in a minimum of time. He regarded as optimal the maintained temperature at which germination began to occur in the shortest time. The minimal and optimal temperatures for seeds of tropical crop plants were found to be higher than for the crop plants of temperate regions but their maximal temperatures were no higher.

Oudemans and de Vries (46) germinated seeds of 16 species of cultivated plants in soil, in greenhouse rooms with temperature ranges from 7°–8° to 15°–21°. Minimal germination temperatures were shown for several species. The lengths of time required for the appearance of the first and last seedlings were found to be shorter as the temperatures were higher but these tests did not include any temperature range so high that germination appeared to be retarded.

LITERATURE OF THE LATER CYCLE

Reynolds (47) germinated the seeds of a number of crop plants at five temperatures between 10° and 32°, noting the germination percentages for several lengths of incubation period. Wheat, maize, and turnip seed received special attention.

For temperature control Atterberg (3) used apparatus somewhat similar to the battery of chambers constructed and described by Livingston and Fawcett (40) but without stirring apparatus. He studied the influence of temperature and incubation time on germinating seeds of wheat, barley, rye, and oats. The seeds were examined at two-day intervals as they lay in folds of linen cloth, and the number of germinated seeds was recorded at each observation. Atterberg's data for oats (3, p. 140, and 39, p. 406) may be used to illustrate several relations that are frequently found in temperature-germination studies. In figure 1 germination percentages are ordinates, constant temperatures are abscissae, and each length of incubation period is represented by a separate graph. For the shortest incubation period, germination was confined to the narrowest temperature range and with successively longer periods the range within which germination occurred became progressively broader. For four days of incubation 19° gave the highest germination percentage and it might properly be called the optimal temperature for that period; for six days the optimal temperature shifted to 15°. Although

this sort of regression of the temperature optimum has been reported by Borthwick (6), Haasis (23, 24), Fawcett (17), Tang (51), and others, many sets of published data show no signs of such a shift. Another notable feature of figure 1, which is common to most such sets of graphs, is a pronounced broadening of the optimal-temperature range to include progressively lower temperatures with longer incubation.

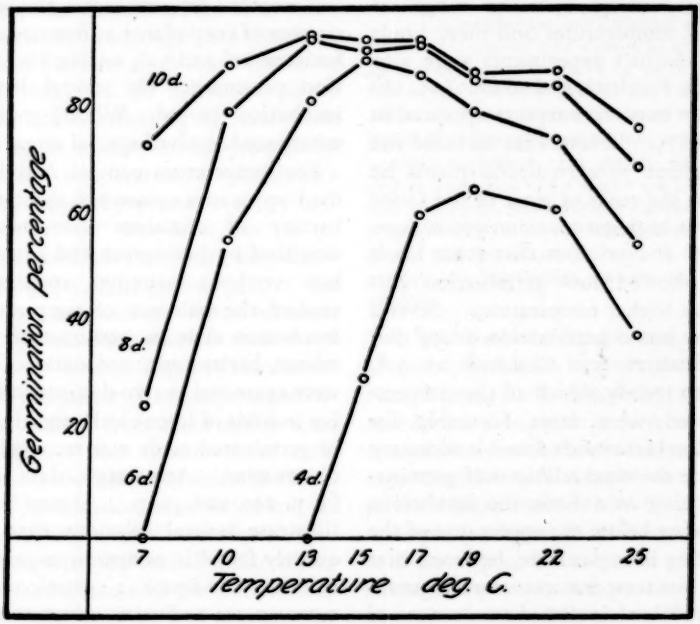

FIG. 1. THE RELATION OF THE GERMINATION OF OATS TO TEMPERATURE
For explanation see text

For all the kinds of seeds tested by Atterberg the germination percentage eventually approached 100 for the lower temperatures, but for temperatures above a critical magnitude the final percentage was progressively smaller with progressively higher temperature. The critical temperature just mentioned was considered by Atterberg to be optimal; it represents the highest temperature at which seedling production was unimpaired. When interest is focussed on securing the maximal number of seedlings from a lot of seed, without reference to the length of incubation, this sort of optimal temperature is more useful than the one defined as the temperature inducing the most rapid production of seedlings.

Atterberg's data for wheat seed six months old show an optimum near 15°; several later workers have reported a similar optimal temperature but others, including some of the earlier workers, find optima nearer 30° than 20°. The extreme variation (15°–30°) in values for the temperature optimum for wheat suggests that specially planned studies will be necessary before the discrepancies already reported may be understood. The work of Wilson and Hottes (54) indicates that

wheat of the same variety grown under diverse climatic conditions has the same temperature relations and that different varieties have about the same responses. The age of the sample, however, is very important; the work of Harrington (31) and Munerati (43, 44) has shown that freshly harvested wheat seed has a low temperature optimum and that during storage it acquires the ability to germinate well at higher temperatures. Atterberg (3) observed similar behavior in barley. This deserves further study, as does the influence of different substrata and various experimental procedures. Such studies might well include not only a broad range of maintained temperatures with short temperature intervals but also short intervals of observation.

Gassner (18, 19) examined the temperature relations of germination for a number of seeds, most of them being light-sensitive or requiring alternating temperature for best germination.

The results of Akemine (1) on the temperature relations of germinating rice seed are representative of those of several workers who studied rice seed—Haberlandt (26), Ocfemia (45), Winkler (55), Jones (33),—and they agree in general with the results reported by Livingston and Haasis (41). The minimum is shown as about 10°–12° and the maximum as about 40°–45°, according to the variety of rice studied and the conditions of incubation. Temperatures between about 15° and about 36° permitted almost complete germination of the samples if sufficient time were allowed, although the rapidity of germination depended upon temperature. Perhaps there is no kind of seed for which the reports of different workers are so nearly in accord.

In the course of experiments on temperature relations of nuclear phenomena Hartmann (32) made some preliminary germination tests at eight constant temperatures between 8.5° and 41°, using moist sawdust as substratum. For seeds of *Phaseolus multiflorus*, *Helianthus annuus*, maize, and pea, 31° induced the earliest appearance of seedlings; at higher and lower temperatures seedlings appeared later.

Harrington (29) carried out temperature studies on seeds of a number of plants cultivated as ornamentals, to gain information concerning the best temperatures for use in seed testing for these forms. For the species tested (of which there were about 18) 15° and 22.5° yielded higher germination percentages than were given by higher temperatures. In a later paper (30) the same writer noted that for several other kinds of seed (Bermuda grass, celery, and Johnson grass, for example) temperature alternation gave far greater germination percentages than did any of the maintained temperatures tested.

Clytee Evans (16) germinated seed of *Amaranthus retroflexus* at nine temperatures between 9° and 46°. The range 21°–42° may be regarded as optimal for rapid production of seedlings, 42° giving most rapid germination.

Coffman (9) incubated seed of about 30 crop plants at several temperatures between 0° and 14°–17°. The seeds were between sheets of wet blotting paper and the temperatures were only approximately maintained. His data show very marked differences among the varieties tested, with respect to minimal temperature for germination; seed of the cereals, clover, alfalfa and several cruciferous plants germinated well at the lower temperatures used, even at 0°.

Dickson (12, 13) germinated seed of several varieties of spring and winter wheat in soils that were maintained at eight different temperatures between 8° and 36°, but he presented no tables or

graphs. He wrote (12, p. 69): "The rate of emergence increased gradually with the rise of soil temperature until at 28° the seedlings reached the surface in from 38 to 48 hours. Above this soil temperature the rate of emergence decreased very rapidly." From this statment, 28° might be regarded as the optimal temperature for the germination of his lot of wheat seed, but in the same paper it is stated that seed of Turkey wheat gave average germination percentages above 95 up to and including a soil temperature of 20°; above 20° the germination percentages were smaller as higher temperatures were used. The performance of Marquis wheat was similar to that of the Turkey variety. According to the criteria used for judging it, the optimal temperature might be set either about 20° or about 28°. Referring to seedling growth, Dickson noted that at 8° and 12° roots developed to a considerable extent before shoots showed much growth, while at a temperature of 28° or higher the tip of the shoot was well above the soil surface before root development became pronounced.

Kreysing (37) and Bär (4) incubated seed of several Festuca species at different constant temperatures between 4° and 33°, noting the germination percentages for various lengths of incubation period and the average incubation periods required for germination at the several temperatures. At 30° and 33° most samples required longer incubation than at the next lower temperature tested.

Borthwick (6) germinated asparagus seed on moist flannel at 10°, 20°, 25°, 30°, 35° and 40°. In the 17 days of his test period no seeds germinated at the highest or at the lowest of these temperatures. For the first four or five days 30° was most favorable for seedling production; after eight days 25° yielded higher germination percentages than either 20° or 30°, but with still longer incubation 25° and 30° gave the same percentage values. From Borthwick's data graphs may be constructed which show a high degree of consistency and are very instructive.

In the course of extensive experiments on conditions affecting seed germination, Morinaga (42) germinated seed of white clover, celery, and water cress under water and on moist filter paper, at seven different maintained temperatures that ranged from 5° to 38°. Seed of white clover and water cress germinated better under water than on moist paper, at all tested temperatures but celery seed germinated at a higher temperature on moist paper than under water. The optimal temperature range for white clover seed broadened from 22°–27° (for a two-day period) to 10°–32° (for a 10-day period). The range 10°–15° yielded the best germination percentages for celery and the range 15°–22° was most favorable for seed of water cress.

Munerati (43, 44) found that newly harvested wheat seed gave low germination percentages at temperatures of about 22°, but percentages as high as 99 were obtained with the temperature range of 5°–7°. This agrees with the findings of Harrington (31). In Munerati's tests a sample of wheat seed that had been stored for a year germinated as completely at 22°–24° as at 12°–14° or at 5°–7°, but only 47 per cent of the seeds germinated at 30°–32°. Wheat stored two years gave low germination percentages, the lowest being for the lowest temperature range tested. Similar results were obtained with other varieties of wheat and other cereals, agreeing with Atterberg's (3) similar findings for barley seed. Differences in germination of samples from different years were so marked that Munerati proposed germination tests at various temperatures as a means of ascertaining the ages of different lots of seed.

Kotowski (36) recorded for each kind of seed tested not only the final germination percentage but also the number of days elapsing before the appearance of the first and the last seedling in each culture, and introduced a coefficient of germination velocity to represent the rate of seedling production. His data and his treatment of them are specially valuable. Seeds of 17 kinds of garden vegetables were germinated in soil at six maintained temperatures between 4° and 30°. For all the varieties studied the incubation time required for the appearance of seedlings was greatest for the lowest temperature tested and became progressively shorter for progressively higher temperatures. This is shown not only by his data for the times of appearance of the first and last seedlings but also by his coefficients of velocity. For spinach, the highest germination percentage is recorded for 4°, which agrees with Sifton's (49) findings. The following quotation is from page 181 of Kotowski's publication: "The optimum for cabbage was 8°C., and for beet 11°C. The advantage of low temperatures may not be significant for cauliflower, carrot, and parsley, the number of seedlings being equal within intervals 8°–11°–18°C. For pea and onion 18°C. was the best, for lettuce, 25°C. and for tomato the range 18°–30°C. was very favorable. The other species employed did not give exact indications upon their optimal points for germination, they probably lay at 30°C. or higher."

Borthwick and Robbins (7) secured final germination percentages of 98 or 99 for lettuce seed incubated on moist flannel at six temperatures between 1° and 25°. Their main lot of seed had been stored 18 months after harvest. For 27° and still higher temperatures the percentage value was much lower than for 25°, which may therefore be regarded as optimal. Kotowski's (36) results with lettuce seed also show this relation. For Borthwick and Robbins's main lot of lettuce seed the highest temperature permitting germination was found to be 29°, but for lots of seed more recently harvested the optimal and maximal temperatures were lower. These writers tested seed of 20 varieties of lettuce and some of the samples used germinated at 29°, but the main lot of seed had integuments of such nature that they apparently limited gas exchange and thereby prevented germination at 30° unless special precautions were taken—such as incubation in an atmosphere rich in oxygen or preliminary soaking at 4° for 4–6 days.

Grimm (22) tested the germination of clover seed in moist sand at four different temperatures. After three or ten days of incubation, cultures at 30° were found to have the highest germination percentages; 20° was slightly inferior in this respect, and 10° and 40° yielded still fewer seedlings, being about equally effective.

Wilson (53) studied the temperature relations of seed germination for three varieties each of wheat and soybean and for one variety of oats, incubating his seeds on moist plaster-of-Paris blocks. For soybean as well as for oats the final germination percentages were not very different for temperatures of 10°, 15°, 20°, 25°, and 30°. His wheat seed did not give as large germination percentages at temperatures above 20° as at lower temperatures, which is essentially in agreement with Atterberg's (3) and Dickson's (12) findings for wheat seed. Different lots of seed of the same variety, but produced in different regions of the United States, exhibited no considerable differences with respect to the temperature relations of germination.

Haasis (23) conducted a series of experiments on the germination of lots of coniferous-tree seeds as related to temperature

and time. Seed of pitch pine (*Pinus rigida*) and some other species began to germinate only at two separate temperature ranges and two optimal temperature ranges consequently appeared for the shorter incubation periods. The proportion of seeds able to germinate at the higher temperatures was small, however, and lower temperatures were much more favorable for the germination of most of the seeds of the lot; but the process went on at a slower rate as the temperature was lower. As a result, with increasingly long incubation periods the optimal temperature range shifted to lower temperatures and the double optimum shown for the shorter incubation periods disappeared. Haasis's seeds of pitch pine tolerated a very wide range of maintained temperatures; at the end of 14 days of incubation some seedlings had appeared at 16° (the lowest temperature tested) and 12 per cent had germinated at 57° (the highest temperature tested); the largest germination percentage (91) was given by 24° maintained 14 days. Unlike most other sets of graphs representing physiological temperature relations, those of Haasis are steepest on the low-temperature side. The temperature giving the greatest germination percentage for a given length of incubation period is taken as the optimal temperature for that length of period. The maximal temperature and the minimal temperature for any length of period are taken as the highest and lowest temperature at which any germination was observed in the specified period. All three of these critical temperature values differ greatly with differences in length of incubation time. For seeds that germinate promptly, such as those of most agricultural plants, the influence of incubation time in modifying the positions of the three cardinal temperatures is easily overlooked unless observations are sufficiently frequent. When germination is slow, however, as in pine seed, the importance of the time factor is readily apparent without specially frequent observations. Haasis called attention to the possibility of sorting or selecting seedlings for subsequent experimentation, according to the time-temperature complex that prevailed during the germination period. This possibility has received further attention from Edwards (14) and from Livingston and Haasis (41).

Meta Bihlmeier (5) studied the relations to temperature and light of germinating seeds of 10 species of the Labiatae and Cruciferae, finding that the optimal temperatures derived from tests with and without light were the same for all forms tested. Optimal temperatures were judged by two criteria; they gave both large germination percentages and high rates of germination.

Fawcett (17) germinated seeds of sweet orange and sour orange in jars of sand kept at nearly constant moisture content and incubated at nine maintained temperatures between 12.6° and 40.0°. His observations extended throughout a period of 105 days. Sweet-orange seed germinated most rapidly at 33° in the first 40 days, but temperatures from 23° to 33° yielded about the same germination percentages with longer incubation. For the 105-day period the minimal and maximal temperatures appear to have been close to 12.8° and 40.0°, respectively. Sour-orange seeds germinated at all temperatures tested except 40°, but in the first 40 days the largest germination percentages were found for 29°. For progressively longer periods the optimal temperature range was extended to lower temperatures more rapidly than to higher ones. After germination the resulting seedlings were grown in light at the same temperatures, and measurements of

seedling height were made. For 30 days 33° appears to have yielded the tallest sour-orange seedlings; for 40 days 26° and 29° were optimal in this respect and after 90 days 23° and 26° were the temperatures giving the best-looking plants. For sweet orange, too, the optimal temperature for seedling growth was lower than the temperature inducing most rapid germination.

Hilda Joseph (34) found exceptionally high minimal temperatures for the germination of birch seed, even after a month's dry storage. Seed of *Betula lenta* germinated only at 32°, the highest temperature tested; that of *B. papyrifera*, *B. populifolia*, and *B. lutea* germinated at 20°, 25°, and 32°, but not at 15°. Alternation of temperature did not increase the germination percentages. Storage in the moist condition at 0° and 5° for two weeks or more so altered the seeds that they afterwards germinated about equally well over a broad range of temperature. The temperature relations of germinating parsnip seed were found by the same author (35) to be altered after prolonged storage.

Bremer (8) germinated beet seed at a large number of temperatures between 3° and 42°, recording the time required for the appearance of the first radicle. The range 22°–36° appears to be optimal, the maximum and minimum fall outside the temperature range tested.

Gericke (21) incubated wheat seeds at the surface of 126 different three-salt solutions at each of seven maintained temperatures between 13° and 35°. All the solutions tested gave about the same germination and early growth and all solutions were superior to distilled water. Temperatures of 28° and 31° yielded the longest seedlings after 110 hours of incubation.

Haasis and Thrupp (24) germinated lodgepole pine (*Pinus contorta murrayana*) seeds on agar at seven maintained temperatures, ranging from 15° to 41°. Their seed samples were collected in British Columbia, from six localities that differed in altitude so greatly as to represent a wide range of ecological conditions. At 19° seeds from the highest elevation showed much better germination than those from low elevations but at 41° seeds from low elevations yielded higher germination percentages than seeds from higher localities. For intermediate temperatures the place of collection exerted no apparent influence on the percentages. As in Haasis's earlier contribution (23), a double temperature optimum was observed for all six samples.

Tang's (51) wheat seeds were submerged in dilute mineral nutrient solution continuously aerated and stirred by means of a bubbling stream of air. He employed seven maintained temperatures and several different degrees of aeration. The optimal temperatures for germination with different combinations of temperature, aeration and time were found to be very different. Depending upon the environmental treatment and the length of the incubation period, cultures at 35°, 30° and 24° were all optimal, the highest temperatures being in combination with low degree of aeration and a short incubation period. Tang emphasizes Haasis's (23) suggestion that germination tests may be valuable in the selection of seedlings for experimentation on later phases of growth.

Lehmann and Aichele's recent review (39) of literature and summary of present knowledge concerning seed germination in the Gramineae constitutes a very valuable work, which will be used by students of seed germination for a long time.

In the course of experiments on the growth of oats Hamada (28, p. 169) made germination tests at four temperatures.

Twenty-four hours sufficed for the appearance of the first seedlings at 24° or 28° but more than twice as much time was required at 36° or 16°. Haberlandt (25) also found earlier germination of oats at 25° than at 16° or at 31°, but Atterberg's (3) results (already mentioned) show different relations.

Gäumann (20) presented the results of Tanja, in part, on the length of time required for wheat seedlings to attain a length of 5 cm. at temperatures between 3° and 36°. At 27° the least time (about five days) was required, confirming Dickson's findings (12, 13); a longer incubation period was required at both higher and lower temperatures—about seven days at 36° and forty-two days at 3°.

Edwards (14) incubated soybean seed on agar plates at five maintained temperatures between 24.5° and 40.0°, making counts of germinated seeds at two-hour intervals. At 33.0° and at 36.5° (a) the least time was required for the appearance of any given germination percentage, (b) the greatest percentage of seeds germinated in any of the incubation periods tested, and (c) the mean incubation time was shortest. The rate of seedling production showed a maximum for the third two-hour interval in which any seedlings appeared. For every one of the five temperatures tested the germination percentage attained when the rate of seedling production began to fall off was found to be 35–40 per cent. With additional time the rate decreased more slowly than it had increased prior to the attainment of its maximal value. Removal of germinated seeds from test cultures at regular intervals was emphasized as constituting a sorting process, distributing the seedlings of a lot into several classes according to their rates of emergence under specified uniform and favorable conditions; the increments of germination percentage from one observation to the next thus indicate the relative sizes of these physiological classes in the original seed sample as well as in the resulting lot of seedlings. This sort of physiological test might be employed when a number of similar seedlings are wanted for experimentation on later phases of development, as was suggested by Haasis (23) and Tang (51) and discussed to some extent by Livingston and Haasis (41).

THE CONCEPT, OPTIMAL TEMPERATURE FOR SEED GERMINATION

The literature on temperature relations of seed germination includes accounts of a number of experimental studies carried out with the purpose of selecting the best maintained temperature for use in viability tests, which constitute a large part of the work of seed-testing laboratories (2). Some accounts deal more directly with the fundamental question of temperature optima for germination, a question that is naturally closely related to minimal and maximal temperatures. With somewhat different aims and with a great variety of experimental procedures, different writers in this field have employed the expression *optimal temperature* with markedly different meanings, some of which may be mentioned in illustration.

(A) Many workers have considered as the optimal temperature for germination the upper limit of a range of temperatures at which approximately the same final percentage of germination is attained when tests are continued long enough to make sure that the maximal germination percentage has been attained.

(B) For a given length of incubation period an optimal temperature may be taken as the temperature yielding the greatest germination percentage at the end of the period. The physiological significance of an optimum of this sort naturally

depends on the length of the incubation period chosen as base for comparisons among the tested temperatures, and the same lot of seed may thus show a number of widely different optima.

(C) Some writers have been specially interested in the time required, at each tested temperature, for the first appearance of any seedlings in a sample of seed and for the appearance of the last seedling. On this basis the optimal temperature may be taken as the temperature at which the least time is required for the appearance of the first or of the last seedling; generally the resulting optimal temperature is the same whether the first or the last seedling is employed. This kind of optimum was the most popular with the earlier workers in this field, frequently it was the only measurement recorded. It has been little used in the last decade, except as supplemental to records of germination percentages. Since the extreme limits of variation with respect to promptness of germination, on which this concept of temperature optima is based, are apt to vary with the number of seeds in the test-sample, it is clear that the size of the sample is important; it should always be relatively large. If a larger and a smaller sample from the same lot of seed are incubated under the same environmental conditions, some of the seeds in the larger sample may be expected to germinate more promptly than any of those in the smaller sample, but if both samples are sufficiently large this kind of difference should not appear. For this reason, as well as for other reasons, results of germination tests that are published without reference to the size of the seed samples employed may be very unsatisfactory.

(D) In some instances the optimal temperature for germination has been taken as the temperature giving the largest average height (or the greatest degree of vigor, etc., estimated in some suitable way) of the seedlings of a set at the end of a specified period for germination and subsequent growth. Such an optimum must refer specifically to the given standard time period, for tests with different lengths of period may of course lead to the choosing of different temperatures as optima. Furthermore, the employment of any criterion of seedling vigor necessitates a confusing combination of the germination process itself with the subsequent enlargement and development of the resulting seedlings; seed germination and seedling growth can hardly be presumed to be related to temperature in exactly the same manner, however germination may be defined.

(E) The temperature corresponding to the least average incubation time may be taken as optimal for the sample, since the behavior of all individuals in the sample is thereby taken into account.

(F) Some authors consider both the mean rate of seedling production and the final germination percentage, when the general temperature optimum for seed germination is to be estimated.

(G) A smoothed temperature curve of germination percentage is sometimes fitted to the plotted points and the temperature corresponding to the peak of this curve is taken as optimal. Considering the great amount of variation in the temperature relations reported by different workers using seed of the same species or variety, and bearing in mind the great importance of experimental technique in the derivation of critical temperature values, etc., it appears that there is as yet no need for such refinement of method and statement.

Whatever may be the criteria and technique employed for fixing upon optimal temperatures for seed germination, the result necessarily involves some standard by which the concept of germination itself

may be limited. All would probably agree that germination represents the earliest stages of renewed growth and development that finally transform a seed into a seedling, but the end of the germination process may be variously defined according to the nature of the study in question or according to the viewpoint of the experimenter. Some writers regard a seed as germinated when the seed coat bursts; others consider a seed as germinated only after the root or shoot has emerged or after shoot or root, or both, have attained a considerable length.

CARDINAL TEMPERATURES FOR SEED GERMINATION

The temperature optimum

For the seeds of most crop plants the optimal temperatures for germination usually fall between 20° and 30° and directions for seed testing (2) usually specify one of these temperatures for incubation. Few optimal values above 30° have been reported; in fact, it is not often that higher temperatures have been tested. When both high final germination percentage and rapidity of germination are taken into account in defining the optimum, it appears that the optimal temperature for maize, rice, and soybean seed lies near 35°. On the other hand, several workers have reported that wheat germinates best at 15°. For several rosaceous seeds that undergo after-ripening 10° or lower may be optimal. Such seeds usually have other physiological peculiarities.

The temperature minimum

Like other physical and physiological processes, minimal temperatures for seed germination are somewhat difficult to establish experimentally. The lowest temperatures at which germination has been observed have shown very slow responses, requiring long incubation periods. It therefore follows that failure of germination to occur at a low temperature and within a given period does not necessarily imply that germination might not be possible with still more prolonged incubation. Although most students of seed germination have not studied minimal temperatures as thoroughly as optimal and maximal temperatures have been studied, nevertheless a number of different kinds of seed have been reported to show considerable or even high germination percentages after sufficiently prolonged incubation at about 0° and under otherwise suitable conditions.

Of course not all failures to secure germination at a low temperature may be ascribed to too short incubation. Although several workers have tested rice seeds at temperatures below 10° germination at such low temperatures has so far not been reported, apparently. A temperature of 14° appears to be too low for the germination of melon seeds.

Of special interest in this connection are the observations of de Candolle (10), Uloth (52), Haberlandt (27), and Coffman (9), on the germination of seeds when in contact with ice. De Candolle reported germination at 0° for white mustard and white clover. Uloth found well developed seedlings of wheat and of *Acer platanoides* in an ice cellar at Bad Nauheim in May, where the temperature presumably had not been above the melting point of ice since the preceding December, when the seeds had accidentally been placed in storage along with the blocks of ice. Wheat roots, for example, had penetrated through half a foot of ice and had grown several inches beyond. Each root was in a channel somewhat larger in diameter than the root itself, which suggested that the growing roots had actually melted their way through the ice, probably by means of heat liberated in respiration.

These observations led Uloth to carry out germination experiments with 25 different kinds of seed. His seeds were on or between blocks of ice with or without soil, and his tests lasted five months. Among common crop plants, seeds of wheat, barley, rye, oats, and pea gave medium or high germination percentages at the end of four months of incubation and seeds of radish, spring cress, white mustard, and hemp gave similar results.

Haberlandt obtained no germination of seeds of wheat, barley, oats, or white clover on ice, after an incubation period of four months; but he reported germination in seed samples of rye, pea, hemp and red clover, after 45 days on ice. He also obtained considerable germination of white mustard and alfalfa seeds on ice and an average root elongation of nearly 1 cm.

Coffman's experiments with seeds incubated on ice lasted only 12 days, but in that short period he obtained germination percentages between 9 and 32 for wheat, barley, rye, alfalfa, and radish. His seed of red clover gave a germination of only 1 per cent in 12 days on ice, whereas Haberlandt reported for this species a germination of 10 per cent after four months of incubation on ice.

The temperature maximum

There have not been many attempts to ascertain the upper temperature limits for germination. Haasis (23), however, reported that some seeds of *Pinus rigida* germinated when incubated at 57°C. De Candolle (10) observed that seeds of *Sesamum orientale* germinated when the incubation temperature fluctuated between 50° and 57° but Haberlandt (26), working with the same species, obtained no germination at 45° although he, too, reported germination at 40°. *Amaranthus retroflexus* has germinated at 46° (16). Rice appears to germinate at 42° but not at 45° (1, 41).

INDEX TO THE LITERATURE ACCORDING TO PLANT FORMS

The studies already noted may be brought together according to the kind of seeds used. In this list are included only kinds of seeds which more than three workers tested.

Wheat. Sachs, 1860 (48); Uloth, 1871, (52); Haberlandt, 1874 (25); Reynolds, 1904 (47); Atterberg, 1907 (3); Coffman, 1923 (9); Harrington, 1923 (31); Munerati, 1925–26 (43, 44); Wilson and Hottes, 1927 (54); Wilson, 1928 (53); Gericke, 1929 (21); Tang, 1931 (51); Gäumann, 1932 (20).

Oats. Haberlandt, 1874 (25); Uloth, 1875 (52); Oudemans and de Vries, 1878 (46); Atterberg, 1907 (3); Coffman, 1923 (9); Wilson, 1928 (53); Hamada, 1931 (28).

Maize. Sachs, 1860 (48); de Candolle, 1865 (10); Haberlandt, 1874 (25); Oudemans and de Vries, 1878 (46); Reynolds, 1904 (47); Hartmann, 1919 (32); Coffman, 1923 (9).

Rice. Haberlandt, 1875 (26); Akemine, 1914 (1); Harrington, 1923 (30); Ocfemia, 1924 (45); Jones, 1926 (33); Winkler, 1926 (55); Livingston and Haasis (41).

Barley. Sachs, 1860 (48); Haberlandt, 1874 (25); Uloth, 1875 (52); Oudemans and de Vries, 1878 (46); Atterberg, 1907 (3); Coffman, 1923 (9).

Peas. Sachs, 1860 (48); Haberlandt, 1874–75 (25, 27); Uloth, 1875 (52); Oudemans and de Vries, 1878 (46); Reynolds, 1904 (47); Hartmann, 1919 (32); Harrington, 1923 (30); Kotowski, 1927 (36)

Beans. de Vries, 1870 (11); Haberlandt, 1874 (25); Uloth, 1875 (52); Oudemans and de Vries, 1878 (46); Reynolds, 1904 (47); Hartmann, 1919 (32); Harrington, 1923 (30); Kotowski, 1927 (36).

Alfalfa and Clovers. de Candolle, 1865

(10); Haberlandt, 1874–75 (25, 27); Oudemans and de Vries, 1878 (46); Coffman, 1923 (9); Morinaga, 1926 (42); Grimm, 1928 (22).

Melon (*Cucumis melo*). de Candolle, 1865 (10); de Vries, 1870 (11); Haberlandt, 1875 (26); Oudemans and de Vries, 1878 (46); Harrington, 1923 (30); Kotowski, 1927 (36).

Beet. Haberlandt, 1874 (25); Oudemans and de Vries, 1878 (46); Reynolds, 1904 (47); Harrington, 1923 (30); Kotowski, 1927 (36); Bremer, 1929 (8).

Radish. Lefébure, 1801 (38); Haberlandt, 1874 (25); Coffman, 1923 (9); Kotowski, 1927 (36).

Lettuce. Uloth, 1875 (52); Coffman, 1923 (9); Kotowski, 1927 (36); Borthwick and Robbins, 1928 (7).

LIST OF LITERATURE

(1) Akemine, M. Zur Kenntnis der Keimungsphysiologie des Reises. Fühlings Landw. Zeitung, 63: 78–93. 1914.

(2) Association of Official Seed Analysts of North America. Rules for seed testing. U. S. Dept. Agric. Circ. 406. 1927.

(3) Atterberg, Albert. Die Nachreife des Getreides. Landw. Versuchsst., 67: 129–143. 1928.

(4) Bär, Karl. Untersuchungen an Rot- und Schafschwingel. Jour. Landw., 76: 129–150. 1928.

(5) Bihlmeier, Meta. Zur Kenntnis der Keimungsphysiologie einiger Labiaten und Cruciferen-Samen. Beih. Bot. Centralbl., 45: 83–96. 1929.

(6) Borthwick, H. A. Factors influencing the rate of germination of the seed of *Asparagus officinalis*. Univ. Calif. Coll. Agric. Tech. Paper No. 18. 17 p. 1925.

(7) ——— and W. W. Robbins. Lettuce seed and its germination. Hilgardia, 3: 275–289. 1928.

(8) Bremer, H. Die Abhängigkeit der Zuckerrübenkeimung von der Temperatur. Angew. Bot., 11: 112–115. 1929.

(9) Coffman, F. A. The minimum temperature of germination of seeds. Jour. Amer. Soc. Agron., 15: 257–270. 1923.

(10) DeCandolle, Alph. De la germination sous des degrés divers de température constante. Biblioth. univ. et revue Suisse, Arch. des sci. phys. et nat. II, 24: 243–282. 1865.

(11) De Vries, Hugo. Matériaux pour la connaissance de l'influence de la température sur les plantes. Arch. Neérland., 5: 385–401. 1870.

(12) Dickson, James G. The influence of soil temperature and moisture on the germination of wheat treated with different seed treatments. Proc. Assoc. Offic. Seed Analysts of N. Amer., 14: 68–72. 1923.

(13) Dickson, James G.. Influence of soil temperature and moisture on the development of the seedling-blight of wheat and corn caused by *Gibberella saubinetti*. Jour. Agric. Res., 23: 837–870. 1923.

(14) Edwards, T. I. Relations of germinating soybeans to temperature and length of incubation time. Plant Physiol. *In Press*.

(15) Edwards, W. F., and Colin. De l'influence de la température sur la germination. Ann. sci. nat., Bot. II, 1: 257–270. 1834.

(16) Evans, Clytee R. Effect of temperature on germination of *Amaranthus retroflexus*. Bot. Gaz., 73: 213–226. 1922.

(17) Fawcett, H. S. Temperature experiments in germinating orange seeds. Calif. Citrograph, 14: 515. 1929.

(18) Gassner, Gustav. Über Keimungsbedingungen einiger südamerikanischer Gramineensamen. Ber. deutsch. bot. Ges., 28: 350–364, 504–512. 1910.

(19) ———. Altes und Neues zur Frage des Zusammenwirkens von Licht und Temperatur bei der Keimung lichtempfindlicher Samen. Ber. deutsch. bot. Ges., 33: 203–217. 1915.

(20) Gäumann, Ernst. Der Einfluss der Keimungstemperatur auf die chemische Zusammensetzung der Getreidekeimlinge. I. Zeitschr. Bot., 25: 385–461. 1932.

(21) Gericke, W. F. Some relations of maintained temperatures to germination and the early growth of wheat in nutrient solutions. Philippine Jour. Sci., 38: 215–238. 1929.

(22) Grimm, Kurt. Über die Keimung des Klees und äussere Einflüsse auf diese. Bot. Arch., 21: 344–445. 1928.

(23) Haasis, Ferdinand W. Germinative energy of lots of coniferous tree seed, as related to incubation temperature and to duration of incubation. Plant Physiol., 3: 367–412. 1928.

(24) Haasis, Ferdinand W., and Adrian C. Thrupp. Temperature relations of lodge-pole pine seed germination. Ecol., 12: 728–744. 1931.

(25) Haberlandt, Friedr. Die oberen und unteren Temperaturgrenzen für die Keimung der wichtigeren landwirtschaftlichen Sämereien. Landw. Versuchsst., 17: 104–116. 1874. (His table 1 is reprinted in Tabulae Biologicae, 5: 191–194. 1929.)

(26) ———. Die untere und obere Temperaturgrenze für die Keimung einiger Culturpflanzen wärmerer Klimate. Haberlandts wiss.-prakt. Unters. auf dem Gebiete des Pflanzenbaues, 1: 117–122. 1875.

(27) ———. Ueber die untere Grenze der Keimungstemperatur der Samen unserer Getreidepflanzen. Haberlandts wiss.-prakt. Unters. auf dem Gebiete des Pflanzenbaues, 1: 109–117. 1875.

(28) Hamada, Hideo. Über die Beeinflussung des Wachstums des Mesokotyls und der Koleoptile von Avena-Keimlingen durch das Licht. Mem. Coll. Sci. Kyoto Imp. Univ. Ser. B, 6: 161–238. 1931.

(29) Harrington, Geo. T. Optimum temperatures for flower seed germination. Bot. Gaz., 72: 337–358. 1921.

(30) ———. Use of alternating temperatures in the germination of seeds. Jour. Agric. Res., 23: 295–332. 1923.

(31) ———. Forcing the germination of freshly harvested wheat and other cereals. Jour. Agric. Res., 23: 79–100. 1923.

(32) Hartmann, Otto. Über den Einfluss der Temperatur auf Plasma, Kern und Nucleolus und cytologische Gleichgewichtzustände. Zellphysiologische Experimente an Pflanzen. Arch. Zellforschung, 15: 177–248. 1919.

(33) Jones, Jenkin W. Germination of rice seed as affected by temperature, fungicides, and age. Jour. Amer. Soc. Agron., 18: 576–592. 1926.

(34) Joseph, Hilda C. Germination and vitality of birch seeds. Bot. Gaz., 87: 127–151. 1929.

(35) ———. Germination and keeping quality of parsnip seeds under various conditions. Bot. Gaz., 87: 195–210. 1929.

(36) Kotowski, Felix. Temperature relations to germination of vegetable seed. Proc. Amer. Soc. Hort. Sci., 1926: 176–184. 1927.

(37) Kreysing, Max. Beiträge zur Keimungsphysiologie des Wiesenschwingels. Jour. Landw., 72: 237–278. 1924.

(38) Lefébure, E. A. Expérience sur la germination des plantes. 139 p. Strasbourg, 1801.

(39) Lehmann, Ernst, and Fritz Aichele. Keimungsphysiologie der Gräser (Gramineen). Stuttgart, 1931.

(40) Livingston, B. E., and H. S. Fawcett. A battery of chambers with different automatically maintained temperatures. Phytopathol., 10: 336–340. 1920.

(41) ———, and F. W. Haasis. Relations of incubation time and maintained temperature to the proportion of seeds germinating in representative tested samples of a lot of rice seeds. *In press.*

(42) Morinaga, Toshitaro. Germination of seeds under water. Amer. Jour. Bot., 13: 126–140. 1926.

(43) Munerati, O. Existe-t-il une apres maturation chez les céréales récemment recoltées? Compt. Rend. Acad. Sci. [Paris], 181: 1081–1083. 1925.

(44) ———. Possibilité de déterminer l'age des graines de blé par la température de leur germination. Compt. Rend. Acad. Sci. [Paris], 182: 535–537. 1926.

(45) Ocfemia, Gerardo Offimara. The relation of soil temperature to germination of certain Philippine upland and lowland varieties of rice and infection by the Helminthorium disease. Amer. Jour. Bot., 11: 437–460. 1924.

(46) Oudemans, C. A. J. A., and Hugo de Vries. Over den invloed der temperatuur op de ontkieming van zaden. Nederl. bot. ver. Leyden II., 3: 309–324. 1878.

(47) Reynolds, J. B. Temperature in relation to seed germination. Ann. Rept. Dept. Agric. Prov. Ontario, 1903: 9–11. 1904.

(48) Sachs, Julius. Physiologische Untersuchungen über die Abhängigkeit der Keimung von der Temperatur. Jahrb. wiss. Bot., 2: 338–377. 1860.

(49) Sifton, H. B. On the germination of the seed of *Spinacia oleracea* L. at low temperatures. Ann. Bot., 41: 557–568. 1927.

(50) Stevens, Neil E. The fad as a factor in botanical publication. Science, 75: 499–504. 1932.

(51) Tang, Pei-sung. An experimental study of the germination of wheat seed under water as related to temperature and aeration. Plant Physiol., 6: 203–248. 1931.

(52) Uloth, [Wilhelm]. Ueber die Keimung von Pflanzensamen in Eis. Flora N. R., 29: 185–188. 1871. *Ibid.*, 33: 266–268. 1875.

(53) Wilson, Harold K. Wheat, soybean and oat germination studies with particular reference to temperature relationships. Jour. Amer. Soc. Agron., 20: 599–619. 1928.

(54) ——— and Charles F. Hottes. Wheat germination studies with particular reference to temperature and moisture relationships. Jour. Amer. Soc. Agron., 19: 181–190. 1927.

(55) Winkler, Hubert. Reis. Wohltmann-Bücher, 3: 1–138. Stuttgart, 1926.

RECENT METHODS OF GENERATING SOUND STIMULI FOR USE IN TESTING THE AUDITORY CAPACITY IN ANIMALS

By MEREDITH P. CRAWFORD and EVERETT G. BRUNDAGE

Animal Laboratory of the Department of Psychology, Columbia University

THE investigation of the sensory capacities of various animal forms has long been a problem of interest to the biologist, general zoologist, and student of comparative psychology. Answers to questions of whether different animals see form and color, are able to distinguish various odors, or are sensitive to musical sounds, have often been sought by many investigators. Not only has the interest been in determining whether or not general sensory fields are functional in particular organisms, but also in finding out within what limits of variation of the external energy the animal may show awareness. Again, problems of how fine are the discriminations that can be made between different qualities of the stimulation energies have been assayed. A great deal of data has been amassed with regard to the sensory capacity of all sorts of organisms.

In considering the action of various forms of energy on the sense organs, two types of problems may be investigated. First, the sensory limits, in terms of the range of variation of the stimulus energy, may be determined, as well as the sensory acuity, or the ability to perceive differences between quantitative manifestations of the same type of energy. Second, neurological problems, concerned with a description of the behavior of the sensory neurones when acted upon by an external stimulus, may be studied.

A general way of attacking the former problem, that of measuring sensory limens and acuity, is by the discrimination method. This consists in presenting the animal with successive situations, alike, as nearly as possible, in all respects, except in the quantity or quality of some energy manifestation peculiar to the sensory capacity under investigation. A measure of the animal's perception of the energy is taken by the efficiency with which it comes to associate a certain response, (usually locomotor), with certain relationships between the stimulus energy manifestations. For example, in investigating the question of color vision in chicks, each animal might be trained to go to one side of the reaction box on being presented with the red light, and to go to the other side when the green light appears. Training of the animal usually takes a number of trials which are spread out over a considerable period of time. Before the results of any discrimination method investigations can be accepted, three general types of controls must have been made during the course of the experiment. These include,

1. The organism must be kept as nearly a constant factor as the progress of maturation and growth will allow during the course of the investigation.

2. The apparatus for presenting the stimulus energies in similar situations must be simple, present no distractions or secondary cues, and afford means of building up a clearly differentiated response for each different manifestation of energy.

3. The physical characteristics of the stimulus must be readily controlled and measured precisely in terms of physical units.

The first two of these problems have been discussed elsewhere, (34), and much work has been done to arrive at satisfactory techniques and apparatus for use in the problem. Concerning the third, in the visual field, pieces of apparatus capable of giving pure monochromatic light of variable intensities and frequencies have already been devised and found useful in animal testing, (34). In the auditory field such accurate stimulus generators have come into use only in recent years. It is the purpose of this paper to discuss at some length the apparatus that has recently become available for the efficient production of precisely controlled auditory stimuli. In neurological as well as sensory range and acuity tests, the stimulus must be subject to very accurate quantification, if any accurate work is to be done in studying nerve conduction phenomena.

OLDER METHODS OF SOUND STIMULUS GENERATION

Until rather recent years the studies of auditory capacity were made with stimuli generated by various kinds of mechanical sounders. These included tuning forks, electrically and mechanically driven; wind instruments, as organ pipes and various forms of resonating columns of air; apparatus producing sound by the fall of one body upon another; and other such devices. These have been critically discussed elsewhere, (6). Here we can only enumerate certain criticisms of their value in quantitative studies. While each criticism does not hold for every type of mechanical sounder, (since some are quite satisfactory in one or two respects), the following may justly be applied only to the lot as a whole.

1. The range of tonal frequencies possible with one instrument or set of instruments is discontinuous.

2. Frequencies of vibration are maintained constant over a period of time only in a few types.

3. The complexity of the sound generated is often uncontrolled, or very difficult of control.

4. Any range in intensity, independent of frequency, is very small.

5. Many pieces of apparatus, if sufficiently large and complex to be of much use, are cumbersome and hard to handle in testing animals.

Four of these criticisms are to be classed as general difficulties encountered by the investigator, which do not make his problem insoluble, but do greatly add to his labor and limit the use to which he may put this type of apparatus. The third criticism, concerning the difficulty of control of sound complexity, might be so serious as to invalidate the results of some investigations employing, for instance, certain types of organ pipes for stimulus purposes in testing pitch discrimination. If harmonics were present along with the fundamental in any appreciable intensity, the animal might easily use these partial tones as secondary cues in responding to the different notes on which it was being trained. While the investigator might suppose that the discriminatory reaction built up to the sounds of two organ pipes is indicative of a discrimination between the two fundamental tones of these, what actually may have happened is that the animal is acting discriminatively to the different upper harmonics of the two tones. This illustrates the necessity of using a pure stimulus.

Adaptability of one instrument to a number of problems is another advantage of some types of apparatus. In sound work, a generator capable of supplying a

wide range of frequencies, at different intensity levels, is obviously more valuable than one not so adaptable. In general, in auditory work, an apparatus capable of generating pure frequencies, or monotonic sound, is most useful. In the following discussion attention will be given to generators capable of rather pure stimulus production.

ELECTRICAL METHODS OF SOUND STIMULUS GENERATION

In recent years sound generators have been made which operate on entirely different principles from those mechanical generators used previously. An electrical current is employed to supply the energy for the sound. This current has a fluctuating potential and is known as an alternating current. By the use of proper devices, depending on electromagnetic or electrothermic principles, this electrical energy may be converted into kinetic energy. This kinetic energy manifests itself in the motion of some object, as a diaphragm, which sets a column of air in sympathetic vibration with it, thus producing the motion of particles of a medium which constitutes the physical basis of sound.

At the outset we may list some of the advantages of most electrical generators over the mechanical ones. First, a continuous tonal range is usually possible over a considerably wide band of frequencies. Rather than going from division to division on the musical scale, as the closest approximation to the continuous range formerly possible with most of the mechanical sounders, (with the exception of the tone-variators, and other wind instruments having resonating chambers of variable length), we are now able to generate from a single apparatus a series of tones representing a continuum from the lowest to the highest frequency or from the longest to the shortest wave length.

Intensity of sound, represented in terms of the amplitude of the sound wave, is also continuously variable over a wide range. This variability is independent of the frequency, and, in general, of the complexity. Intensity of the sound is governed by the power of the electrical current being transmitted. Thus, for a frequency of 512 c.p.s., a range from fractional parts of a watt up to the capacity of the instrument may be produced, which may be transmitted into a sound varying continuously from below the sensation limit to intensities approaching the pain limit for human subjects.

Complexity of the wave, or quality of the sound, represented by the harmonic content of the wave, is perhaps least controlled of these three properties. By percentage of harmonic content is meant the per cent of the intensity of the fundamental that is the total intensity of the combined harmonics appearing in the wave. In general, there is apt to be a greater harmonic content at the lower end of the frequency range than at the upper. Often we find in commercial pieces of apparatus that the harmonic content is doubled at frequencies lower than 100 c.p.s. Oscillators are now on the market with a harmonic content of not more than 3 per cent at the maximum, and may be reduced to 1 per cent in the upper ranges. For the majority of commercial oscillators now obtainable the maximum harmonic content is not more than 10 per cent.

As a check on the controls of frequency, intensity, and complexity available with electrical generators, there are obtainable a number of devices for measuring the electrical current or the output sound in terms of these properties. The ability to read frequency, intensity and complexity of the sound at the working point greatly facilitates accurate work with the auditory studies. These measuring devices, whose

importance cannot be overemphasized, will be discussed in more detail below.

Perhaps the discussion of electrical sound generators may best follow the three general functional units of the generation process. First, we will consider methods of generating an alternating current. How the energy of this current may be transmitted into sound waves will be the subject of the second section. A third will be devoted to some consideration of the devices useful in measuring the current and output sound wave.

1. *Electrical Oscillation Generators*

Of the variety of ways in which an electrical oscillation may be generated, two general methods have found more or less extensive application in electrical sound production. The first type is dependent on the principles of magnetic induction, and includes the ordinary types of rotary alternating current generators, and various modifications of this general type. The second type uses the thermo-ionic vacuum tube as a source of alternations. These two types will be discussed separately below.

In the first, or electro-magnetic type, the electrical potential or electromotive force is built up in a conductor by its motion through a magnetic field of force. The rate of cutting lines of force determines the strength of the current or the amount of electromotive force built up, and the direction in which the lines are cut determines the polarity of the conductor, or the direction of the flow of current in the wire. An alternating current generator of the rotary type is so designed that equal numbers of magnetic lines of force will be cut by a conductor in successively equal periods of time, but in opposite directions each time. The field, or set of electromagnets which build up the field of force, and the armature, or set of conductors in which the current is induced, are made to rotate with respect to one another. This rotation causes lines of force in each half of the rotation to be cut in successively opposite directions, and the number of lines being cut to follow a sinusoidal curve. Thus, when the armature is connected in an external circuit, we have a means of obtaining an oscillating electrical current which is approximately sinusoidal.

The ordinary commercial generator has been used in audio work, but its usual heavy type of construction and wasteful output has made it rather uneconomical in sound production. The current emitted is known to be free from harmonics if the circuit is not overloaded.

Other lighter and simpler machines have been designed and used by investigators of the auditory capacity. The Dolezalek Toothed Wheel, the type of apparatus used by Stewart, (30), in 1920 and by Trimble, (32), in 1931, is described in a text on sound by Wood, (43). The output of this generator is rich in harmonic content, and requires the use of a number of wave filters before the final current delivered approximates a pure sine wave. Another slightly different type of rotary alternator has been designed and used by Beasley, (2, 3), in 1931. Very nice precision has been attained with this instrument.

In general, the frequency of oscillation of the rotary alternators may be varied by varying the speed of the rotation of the moving parts. This speed is rather hard to keep constant, and therefore makes the frequency subject to a good deal of variation, though a single frequency may be accurately maintained by the use of a synchronous motor operating on a commercial alternating current, (whose frequency is maintained at a very constant value).

Intensity is controllable either by the use of suitable resistances in the hookup,

or by varying the distances between field and armature, which is easily effected in such instruments as that of Beasley.

Control of complexity will be more fully discussed under the section on filtration.

Perhaps the chief advantage of the rotary inductor type of oscillator is the ability to control phase relationships of two or more currents which may be generated simultaneously. By mounting more than one inductor on the same shaft, as many alternating currents may be produced. By rotating the fields of these, the phase relationships of the currents may be varied at will. Also, currents may be generated from these inductors which are in definite frequency ratios to one another. By mounting inductors whose poles are in simple numerical relations, frequencies may be obtained which bear a simple numerical ratio to one another.

Aside from the obvious disadvantage of moving parts and cumbersome construction, this type of generator has proven very satisfactory in a number of auditory investigations. It is to be regretted that there are so few rotary inductors for laboratory work commercially available.

Electrical oscillators dependent upon the operation of vacuum tubes are fast becoming the standard source of alternating current for the production of sound. A number of oscillators, designed especially for the audio frequencies, are now on the market. Their compactness, silence, and smoothness of operation render them much more acceptable in the ordinary work requring sound generators. Units including amplifiers and wave filters, as well as the primary oscillators, may be obtained. Our discussion will follow divisions of oscillation generation, amplification, and filtration, the three functions that must be performed to obtain a satisfactory current for transmission into sound.

Vacuum tube oscillators are of three general types, the Self Oscillators, those dependent on Dynatron principles, and the Heterodyne, or Beat Note oscillators. These will be discussed in turn.

From an understanding of the amplifier function of the simple triode vacuum tube, (for an explanation of this the reader is referred to texts on general physics as, (16, 37)), one may easily pass to a comprehension of the operation of the self oscillator. (See Figure 1.) Instead of introducing a fluctuating potential on the grid of the tube from some outside source, as in the amplifier circuit, the grid circuit may be supplied by inductance from the plate circuit, by simply connecting each to the primary and secondary coils of an induction coil. A slight change in potential of the plate circuit, such as obtained by switching in the B battery, will be reflected in a change in potential on the grid. Since the plate current is controlled by the potential on the grid, another change will thus be caused in the plate circuit. Due to the resonating ability of the condensers and coils in the plate circuit, these fluctuations tend to repeat themselves, and come to be maintained in a continuous series of oscillations in the plate circuit, which may be used as the alternating current desired.

Dynatron principles, or the Delta Ray Phenomenon, have been employed in another type of vacuum tube oscillator hookup. This phenomenon consists in the emission of electrons from a cold electrode when it is bombarded by electrons moving at a speed greater than a certain critical velocity. For example, (See Figure 2), the electron discharge carrying the plate current may impinge on a heavy grid between filament and plate at such a velocity as to set up a secondary emission of electrons therefrom. This loss of electrons by the grid may so change its potential as to lessen or stop the primary flow of electrons from filament to plate, due to the grid's

valve action upon the plate current. A cessation of primary electron bombardment naturally stops the secondary emission, and thus increases the positive potential on the grid. By proper arrangement of the external circuit, this fluctuation of net potential on the grid may be caused to repeat itself, and therefore to be reflected in a fluctuation of the plate current. Thus another type of source of alternating current is available.

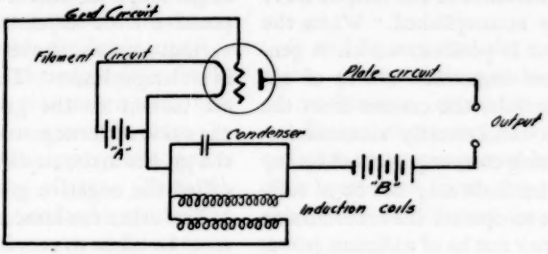

FIG. 1. SELF OSCILLATOR CIRCUIT
Adapted from Fig. 391, Webster, Farwell and Drew (37)

The Heterodyne, or Beat Note, type of oscillator combines the operation of either of the above types of oscillators as primaries, which feed their output of alternating current into a mixer tube. The resulting alternating current obtained from the mixer tube equals in frequency the difference between the frequencies of the two primary tubes, or represents a "beat-note" frequency combined from the two. Hence the alternative name of this type of oscillator.

Both of the two general types of single oscillator hook-ups have been employed in making successful oscillation generators. Commercial instruments are obtainable operating on Self Oscillator and Dynatron principles. Heterodyne oscillators have come into favor because of their elimination of certain objectionable fluctuations of frequency due to the variation of power supply to the primary oscillators. If the voltage of the power to the primary or single oscillators be varied, the frequency of the generated oscillations will vary. Often it is inconvenient to maintain a power supply free from the possibility of variation. If two tubes, which have been carefully matched for response characteristics, be used in combination, as in the Heterodyne circuits, any fluctuation in the power supply will affect both primary oscillators in the same way. Since the frequency of the beat note is dependent on the difference between the frequencies of the two primaries, it will be quite unaffected by the simultaneous variation in both primary tubes. The frequency of the Heterodyne current output is controlled by the variation of the frequency of one oscillator while the other is held constant.

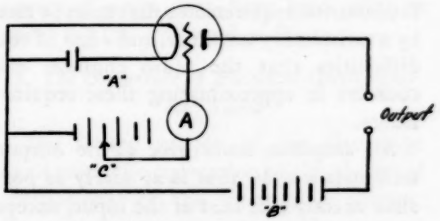

FIG. 2. DYNATRON OSCILLATOR CIRCUIT
Adapted from Van der Bijl p. 48 (33)

Perhaps the greatest advantage of the Beat Note oscillator is the ability to control the frequency of the output from a single

dial. Numerous dial settings for every change of frequency, such as are usually necessary with the self oscillators, greatly delay the work of investigators. This facility of control also applies to the filtering out of undesired harmonics. Since the oscillators, when used as primaries in the Heterodyne, are usually operated at higher frequencies than when used directly for audio work, filtration of the output wave is more easily accomplished. When the primary output is purified, which is generally the most important source of objectionable partials, the current from the mixer tube is satisfactorily sinusoidal.

The alternating current generated by any of the above methods may not be of sufficient strength to operate the transmission device, or it may not be of sufficient power to allow for a large range in intensity of the sound wave generated. Therefore, usually there must be included in the hookup some amplification unit by which the power level of the oscillating current may be raised. Reference has already been made to the simple amplification function of the single triode tube. Here we will only attempt to point out some of the fundamental requirements that must be met by a satisfactory amplifier, and a few of the difficulties that the radio engineer encounters in approximating these requirements.

An amplifier must give at its output terminals a wave that is as nearly as possible exactly like that at the input, except at a higher power level, (larger amplitude). In other words, no *distortion* of the wave must occur in the ideal system. Three common causes for this distortion are as follows: (1) the amplifier may respond to some frequencies more than to others, (2) at any frequency a variation in input power may not produce a corresponding change in output power, (3) when complex tones are being amplified, the phase relationships of the components may be altered.

In order that all these possible distortions may be either eliminated or compensated for, numerous hookups and tube designs have been made, each possessing characteristic advantages and disadvantages, depending on the use of the apparatus. We shall point out only two fundamental requirements that must be fulfilled in amplification. First, if the grid of a single amplifier tube is allowed to become positive with respect to the filament, for various reasons, the response of the circuit is no longer linear. Therefore, the strongest current to the grid must not exceed the value of the negative potential at which the grid is maintained below the filament, called the negative grid bias of the tube.

The other fundamental precaution that must be taken to prevent distortion is that the impedance of the plate circuit must be in definite ratio to the impedance of the external circuit. The "impedance matching" between the amplifier tubes and the external circuit must be carefully determined for each particular circuit being used.

Simple though these requirements may seem, they may be met or closely approximated only by the careful work of the experienced engineer. A great deal of work has been done to design amplifiers which will operate without distortion, but a consideration of these engineering problems is quite beyond our present intent. We shall point out only the more common types of general hookups where more than one tube is used for amplification.

Units or stages of amplification may consist of one or more tubes acting together to produce amplification of a certain ratio. The "push-pull" hookup, in which two tubes operate at a phase difference of 180°, has been found one of the most useful in each stage, since the harmonics due to overload are more or less balanced out. A variety of methods have been employed in connecting successive stages of amplification. These include coupling directly,

by means of resistances, or through transformers. A combination of the resistance and transformer type of coupling has been found very satisfactory. Since the advent of the screen grid tube, the resistance couple has come into greater use. For a more complete technical discussion of modern types of amplifiers, the reader is referred to an article by Smiley, (29).

Reference has already been made to the possibility of the generation of harmonic frequencies along with the fundamental in the oscillator, or to their formation in the amplifier units. As was mentioned, these may be eliminated to a certain extent by the use of filters at appropriate points throughout the total circuit. These filters all operate as resonators tending to damp out certain ranges of frequencies, and are of three general types. Low pass filters are those designed to eliminate all frequencies above a certain limit. Band pass filters are those which are to eliminate all frequencies on either side of a certain band of frequencies, or below a certain lower limit and above a certain upper limit. High pass filters are those which eliminate all frequencies below a certain value.

In using these filters effectively for the elimination of partials, the frequencies of the same must first be determined, and then the proper filters, which are obtainable commercially, must be hooked in. It will be seen that in a generator where a wide frequency range is possible, the use of fixed frequency filters is greatly limited in the purification of oscillations at different frequencies. To completely eliminate harmonics over the entire range, complicated systems of adjustable filtration devices are necessary. It should be noted that in the ordinary commercial oscillator, different parts of the frequency range are more free of harmonics than are others. In the ranges of large harmonic content, fixed frequency filters may be effectively used, while none may be needed in the other ranges.

It will be seen that the completed oscillation generator may include three types of mechanisms, those for generating the oscillation, those used to amplify this oscillation to proper power levels, and possibly numerous filters for purification of the waves at different frequency ranges.

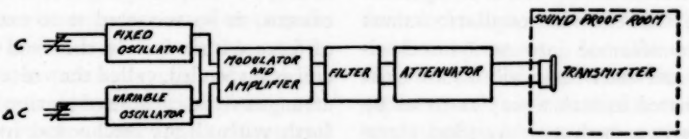

FIG. 3. TYPICAL COMPLETE HETERODYNE OSCILLATOR CIRCUIT
Taken from Shower and Biddulph (28)

Schematic diagrams of the complete generator units that have been used in audio testing are found in Figure 3.

2. *The Conversion of Electrical Oscillations into Sound*

The second section of our discussion deals with the conversion of the electrical oscillations, or the alternating current, into sound waves, or, to speak more accurately, the transformation of the periodic electrical energy into the kinetic energy of the oscillation of the particles of a medium, which constitutes the physical basis of sound. In choosing the type of transmitter for use in auditory investigations, the type of problem largely determines the selection. If the subject must be in motion during the test, as is the case

in the animal discrimination problems in set ups like the Yerkes-Watson Box, sounds must be emitted which are of sufficient strength to carry more or less uniformly over the whole apparatus. If the problem requires that the subject remain stationary, various types of transmitters which may be placed in close approximation to the external auditory meatus may be used. In the former case, some sort of *loud speaker* must be employed, while in the latter, some sort of *earphone*, including the thermophone, is available for use. Our discussion will follow the natural divisions based on the construction of various transmitters, either of the loudspeaker or earphone type, rather than being divided in these two ways.

The convertor must perform two general functions. The electrical oscillations must first be transformed into mechanical vibrations, and then these vibrations must be transmitted in such a way as to set up vibrations in a medium. An ideal transmitter would be that instrument whose output of sound waves, if measured graphically, would represent exactly in waveform and frequency, as well as relative amplitude, the waveform of the alternating current being introduced from the generator. Perfect reproduction is well nigh impossible, though some devices approximate it much more nearly than do others. Two types of transmitters will be discussed here, the one depending on electromagnetic principles, and the other depending on the heating effect of an electric current.

Electromagnetic Transmitters: The ordinary telephone receiver at once suggests itself as a possible transmitter dependent upon electromagnetic principles. It has been shown elsewhere, (6), that distortion of the waveform is produced by transmitters of this type, both on account of the delays in response of the magnets involved, and the peculiarities of the vibration of the diaphragm which acts as armature for the magnet, as well as a device for setting the particles of the surrounding medium into vibration. Magnetic loudspeakers, as well as numerous radio headphones of the earlier types, are subject to the same criticisms. Since much better devices are now available, which have already almost completely displaced the old magnetic transmitters, we will omit any further discussion of these types.

The most modern transmitters now in general use, both as headphones and loudspeakers are, while still operating on electromagnetic principles, of somewhat different design. These "Dynamic" transmitters may be briefly described as follows: A coil of wire, carrying a constant direct current, is so mounted as to exert a field of force within it. In this field a lighter coil is suspended, called the voice coil, and arranged to be capable of motion back and forth with slight mechanical impedance. The alternating current to be transmitted is introduced into the voice coil, and as it builds up a fluctuating field of force which acts against the fixed field, the voice coil is given a mechanical motion that is known to be a rather faithful reproduction of the oscillation of the alternating current. This motion is transmitted by levers, or other mechanisms of small mass, to a device for setting the atmospheric medium into vibration. In the case of moving coil telephone receivers this is a lightly constructed diaphragm, while in certain loudspeakers it is a small metal disk at the end of an air filled horn. Again, it may be a large cone usually made of some parchment-like material.

In the case of the earphone distortion may be produced by the sympathetic vibration of the diaphragm in its natural period, or some multiple thereof. This results in a "peaking" of the intensity

response curve at such frequencies. If, as in many loudspeakers, a horn is used, a similar peaking in the response curve is noted at frequencies that are near multiples of the natural period of the column of contained air. So great is the resonant reënforcement of these horns at some characteristic frequencies, that for an input current of constant power level, the intensity level or amplitude of the sound wave would vary tremendously, as is illustrated by typical horn response curves (22, pp. 156–166).

Where cones are used to transmit the mechanical vibrations to vibrations of the particles in a medium, somewhat the same effect is noted, due to the resonant vibration of the cone at characteristic frequencies. A baffle has been successfully used with these transmitters in an effort to make more linear the frequency response curve. Just what the precise function of the baffle may be, beyond its prevention of the interference between waves from the front and rear of the cone, is not known. Its effect in leveling the response characteristic, however, is undeniable.

The advantage which probably has led to its general adoption in commercial sound work is the ability of the Dynamic speaker to handle large intensities of current and sound without overload and with consequent fidelity of reproduction.

In the design and construction of the total earphone and loudspeaker units engineers have attempted to balance, as much as possible, the various tendencies toward distortion due to the vibration of different parts in their natural periods. The final response curves have been smoothed out more than the above criticisms might seem to indicate. Also, it should be noted that many of the tests of loudspeakers have been made in rooms where the reflection, reverberation and interference effects on the sound waves have not been entirely eliminated, so that the curves plotted do not necessarily give a true picture of the transmitter's operation. The actual response curves may be better than these tests show. Problems of testing will be more fully discussed below.

Thermophones: Another type of receiver, depending on entirely different principles, has been successfully placed on the market. The thermophone, developed by Arnold and Crandall (See Wente, 38) offers possibilities as a very accurate transmitter, though the sound waves generated are very feeble. This type of instrument consists essentially of a small wire of platinum or other resistant metal, stretched between two electrodes in a small metal capsule, having a minute opening to the exterior in its outer wall. A direct current conducted through the wire heats it to constant temperature. An alternating current, the one to be converted into sound, is superimposed on the direct current, and produces fluctuations in the temperature of the wire. It is noted that the temperature fluctuations are communicated to the air immediately surrounding the wire almost as soon as the wire itself changes temperature. These fluctuations produce corresponding variations in air pressure, which are communicated as vibrations to the wall of the capsule, and result in audible sound waves.

It has been found by careful testing that the waveform of the sound generated by the thermophone is a very accurate reproduction of the waveform of the alternating current introduced. The amplitude, however, is generally so small, and the sound consequently so weak, that the apparatus must be placed in the external auditory meatus of the mammalian subject before the sounds may be heard. Beside the unnaturalness of this location of the sounding device, the possibility of bone conduction, rather than air conduction, of the sound

presents a serious objection to the use of the thermophone. The advantage of the extremely smooth response characteristic curve, the best, perhaps, for any transmitter now available, is almost overbalanced by the inconvenience of its application, and the possible unreliability of results with its use.

In the near future these two general types of transmitters will probably not include the available models. New designs are constantly being tried for phones and loudspeakers, depending on principles not formerly employed. Promising models have been built experimentally depending on principles of electro-static attraction and friction on a rotating drum, on the use of an air valve employing the piezo-electric effect, and many other electrical phenomena. None of these have been manufactured up to the time of this writing, though within a few years entirely new designs may have replaced those now extant.

3. *The Measurement of Electrical Oscillations and Sound*

As has already been mentioned, one of the advantages of the use of electrical sound generating apparatus is the ability to measure the sound produced at the working point. Throughout the total generator hookup, the oscillator, amplifier, and transmitter units, it is often useful and necessary to get a measure of the electrical oscillation as it is coming through. Also, for any accurate work, the sound, as it is emitted from the transmitter, or as it enters the external auditory mechanism of the animal, must be subjected to quantitative analysis. Various electrical devices may be obtained for use in measurement at both these two general localities. These instruments may be placed directly in circuit with the generator units, or, when measuring the sound produced, may be used in connection with a microphone, the device for converting sound energy to electrical energy. In this latter measurement, that of the sound waves, many problems arise concerning the conduction of a sound wave through the atmosphere. These will be briefly discussed below. In this section we will note a few of the most useful measuring instruments, and instruments for converting sound into electrical energy.

Indirect measurements of all three properties of a sound, its intensity, frequency, and complexity, may be obtained from a single instrument, the oscillograph. The use of special meters for each, however, is found much more satisfactory. A few of these will be mentioned.

Frequency is usually measured indirectly, that is by comparison with some standard of frequency. This may be done by the "method of beats," that is, by counting in terms of the beat notes the difference between the standard frequency, as a tuning fork or reed, and the frequency being measured. A more common method is by means of resonance. The frequency is so varied that the standard is set into resonant vibration. When this is accomplished, the variable frequency is known to be some multiple of the standard. This method is employed on commercial oscillators, being equipped with a reed or vibrating needle, which is set into resonant oscillation at the proper frequencies. Knowing the frequency of the standard, it is easy to check the calibration of the oscillator dial, by noting its reading when the standard is in vibration. It is known that reeds and metal needles under constant temperature conditions, maintain a relatively fixed period of vibration, or vary regularly with temperature changes. Instruments may be obtained which read frequency directly when connected in an alternating current circuit. These operate on a certain type of bridge circuit.

Intensity of electrical oscillation, and

therefore of the generated sound, is measured in terms of electromotive force. Some form of voltmeter is useful in this connection, in particular the vacuum tube voltmeter, because of its extreme sensitivity to small amounts of current, and of its very large resistance. Instruments have been sold recently which measure the current directly in terms of decibels, the unit of sound intensity based on the sensitivity of the human ear. If amplification ratios are known, it is possible to determine very accurately the intensity of the sound as it is being generated from the transmitter, or as it is being received at the microphone, provided conversion ratios of speakers and microphones are known.

Waveform or complexity of oscillations is subject to very accurate analysis by the graphic representation given by various forms of the oscillograph. The oscillographs now in general use are essentially mirror galvanometers, which, by magnetic action, follow the oscillation and strength changes of the electrical current introduced. A beam of light reflected by the moving mirror is focused on a revolving mirror or moving photographic film, thus tracing the outline of the motion on a two coordinate graphic system. The best type of oscillograph is quite accurate for frequencies below 10,000 c.p.s., but above this general value the sympathetic vibration of the moving parts distorts the response curve. Oscillographs whose moving parts have practically no mass, being simply a stream of cathode ray discharge, are not subject to this criticism, and may be used to measure oscillations of very high frequencies. The cathode rays, or discharged electrons in a special vacuum tube, can follow any variation in movement made by the electrons flowing in the external circuit, and therefore afford an almost perfect means of observing the fluctuation of the alternating current. Recent developments have overcome the former difficulty in using the cathode ray oscillographs, by allowing a continuously moving curve to be shown on the luminescent screen, rather than the old tracing of Lassajous's figures. Also the photography of the wave is becoming more practicable.

Brief mention must be made of the devices for converting sound into electrical current. Of the numerous designs that have been brought forth, the condenser, ribbon, and dynamic microphones have been found most satisfactory for laboratory use, in the order named. Condenser microphones give best reproduction of the sound wave, due to the delicacy of their electrostatic operation. Ribbon microphones are especially useful because of their directional properties, responding more or less exclusively to waves coming from only one direction. Dynamic microphones are just the reverse of dynamic loudspeakers referred to above, and are subject to similar criticisms. The older carbon microphones, though still in wide use, lack the power of accurate reproduction, due to their peculiar construction of carbon granules. Difficulties of "packing" and "frying" practically eliminate them for use in this type of laboratory work.

Measuring devices, which must be constantly and intelligently employed, may form a permanent part of the total generator circuit, or may be available for immediate temporary connection therein. When the sound is to be measured, it is often necessary to include amplification units in the circuit before the measuring devices may be operated. The difficulties mentioned above with regard to amplifier design apply with equal force here. Also, if amplifiers are used, conversion ratios must be accurately determined in order to properly measure the sound.

The changes that may take place in the sound wave as it passes from the trans-

mitter to the pick up microphone suggest some of the problems involved in measuring an accurately quantifiable auditory stimulus reaching the subject after leaving the loud speaker. Obviously, if some form of earphone is used, these acoustical problems need not be considered, except in relation to the exclusion of external noise from the experimental set up.

The distortion of a sound wave in a closed room is caused by the reflection, refraction, and interference of the waves. Perhaps the easiest way to lessen these three is to stop, in as far as possible, the reflection, and thus the refraction. This may be accomplished by covering all reflecting surfaces, the walls of the experimental room and those of the apparatus, as well as any other hard surfaces in the enclosure, with some sort of absorbent material. The effectiveness of the material in preventing reflection is measured in terms of its absorptive coefficient for various thicknesses of material at different frequencies. In choosing an anti-reverberation material, care should be taken to get one whose absorptive coefficients are nearly the same over the frequency ranges called for in the experiment. In general, the thicker the material, the more nearly are the absorptive coefficients equal at different frequencies. Various kinds of felts and other porous materials are now on the market which may be effectively used for this damping function.

CONCLUDING REMARKS

As may be seen from the above discussion, electrical sound generation is by no means in a static state. There are still many problems of refinement of the apparatus which are yet to be solved before perfect generation is possible. Such rapid strides are being made in the development of sound apparatus for radio and telephone work that the experimental results of the sound investigators are sure to bring about the manufacture of better generators in the near future. At present, however, we may fairly conclude that electrical sound generators, although still complicated and involving many problems, are the best sources of sound that have been so far devised for use in auditory investigations. It will be interesting to follow the future developments in this field, with a view of the application of new devices to the technique of testing animal auditory capacity.

This paper is written from a thesis prepared under the direction of Professor C. J. Warden.

LIST OF LITERATURE

In this bibliography are included articles and books explaining the operation of various electrical apparatus, or reporting auditory investigations in which they were used, and the catalogs of certain manufacturers of electrical sound apparatus.

(1) Banister, H. The effect of binaural phase differences on the localization of tones at various frequencies. Brit. J. Psychol., 1925, 15, 281-308.

(2) Beasley, W. Differential response to cyclic phase variation in compound sounds. J. Gen. Psychol., 1931, 5, 229-51.

(3) ———. An audio frequency compound alternator with independent control of frequency, intensity, and phase. J. Gen. Psychol., 1931, 5, 415-21.

(4) Crandall, I. B. Sounds of speech. Bell Teleph. Syst. Tech. J., 1925, October, v. 4.

(5) ———. The Theory of Vibrating Systems and Sound. New York, 1926, Van Nostrand, 272 p.

(6) Crawford, M. P. Methods for generating sound stimuli for use in testing auditory capacity. Master's essay, 1932, Columbia University, New York.

(7) Davis, A. H. and Kaye, G. W. C. The Acoustics of Buildings. London, 1927, G. Bell, 216 p.

(8) Elway, T. The microphone, radio's electric ear. Radio News, 1932, 13, 555 ff.

(9) Fletcher, H. Speech and Hearing. New York, 1929, D. Van Nostrand, 331 p.

(10) FLETCHER, H., AND WEGEL, R. L. The frequency sensitivity of normal ears. Physical Rev., 1922, 19, 553–65.

(11) FREE, E. E. Radio's powerful electric voice. Radio News, 1932, 13, 759 ff.

(12) GENERAL RADIO COMPANY, Cambridge, Mass. Catalog F., Parts 1, 2, 3, June 1930 to October 1931.

(13) FREDRICK, H. A. The development of the microphone. J. Acous. Soc. of Am., 1931, 3, No. 1, Part 2, 25 p.

(14) GUNDLACH, R., and BENTLEY, M. The dependence of tonal attributes upon phase. Am. J. Psychol., 1930, 42, 519–43.

(15) HALVERSON, H. The audio oscillator. Am. J. Psychol., 1927, 38, 294.

(16) KIMBALL, A. L. A College Textbook of Physics. 4th ed. New York, 1929, Henry Holt, pp. 190–252, 516–23, 527–36, 541–543.

(17) KNUDSEN, V. O. The sensibility of the ear to small changes of intensity and frequency. Phys. Rev., 1923, 21, 84, 102.

(18) LEWIS, D. How to build your own beat frequency oscillator. Radio News, 1932, 13, 580 ff.

(19) LLOYD, M. G., and AGNEW, P. G. The effect of phase of harmonics upon the acoustic quality. Bull. Bur. Standards, 1909, 6, 255–63.

(20) MANNING, F. B. Hearing in rattlesnakes. J. Comp. Psychol., 1923, 214.

(21) ———. Hearing in goldfish in relation to the structure of the ear. J. Exp. Zool., 1924, 41, 520.

(22) MILLER, D. V. The Science of Musical Sounds. New York, 1928, Macmillan, 286 p.

(23) MUENZINGER, K. F., and GENTRY, E. Tone discrimination in white rats. J. Comp. Psychol., 1931, 12, 195–205.

(24) OLSON, H. F. Mass controlled electrodynamic microphones. J. Acous. Soc. of Am., 1931, 3, 56–68.

(25) PAVLOV, I. Conditioned Reflexes. 1927, Oxford Univ. Press, Humphry Milford, p. 20 (For a discussion of the sound proof laboratory.)

(26) R. C. A. VICTOR COMPANY, Camden, N. J. Laboratory and test instruments, Bulletin "A," June, 1931.

(27) REISZ, R. R. Differential intensity sensitivity of the ear for pure tones. Phys. Rev., 1928, 31, 867–75.

(28) SHOWER, E. G., and BIDDULPH, R. Differential pitch sensitivity of the ear. J. Acous. Soc. of Am., 1931, 3, 275–87.

(29) SMILEY, G. The output stage in sound transmission. Projection Engineering, 1932, 4, Feb.

(30) STEWART, G. W. The function of intensity and phase in the binaural location of pure tones, Part II, Phase. Phys. Rev., 1920, 15, 432–45.

(31) TITCHENER, E. B. Experimental Psychology, v. II, Quantitative experiments, Part 2, Instructor's Manual. New York, 1923, Macmillan, p. 60.

(32) TRIMBLE, O. C. An apparatus for the study of the relative rôles of phase and intensity in sound localization. Am. J. Psychol., 1931, 43, 638–40.

(33) VAN DER BIJL, H. J. The Thermo-ionic Vacuum Tube and its Applications. New York, 1920, McGraw-Hill, 391 p.

(34) WARDEN, C. J., JENKINS, T. N., and WARNER, L. H. A Textbook of Comparative Psychology. New York, 1933, Ronald Press.

(35) WASHBURN, M. F. The Animal Mind. New York, 1926, Macmillan, 106–24.

(36) WATSON, F. R. Sound generators. Int. Crit. Tables, 1929, 6, 453–57.

(37) WEBSTER, D. L., FARWELL, H. W., and DREW, E. R. General Physics for Colleges. New York, 1926, Century Co., pp. 532–50, 182–207.

(38) WENTE, E. C. The thermophone. Phys. Rev., 1922, 19, 333–45.

(39) ——— and THURAS, A. L. Moving coil telephone receivers and microphones. J. Acous. Soc. of Am., 1931, 3, 44.

(40) WEVER, E. G. The upper limit of hearing in the cat. J. Comp. Psychol., 1930, 10, 221–223.

(41) ——— and BRAY, C. W. The nature of the acoustic response. J. Exp. Psychol., 1930, 13, 373–87.

(42) WIRELESS EGERT ENGINEERING, INC. 179 Varick St. New York, Instruments and developments, Catalog "B." Received April 1, 1932.

(43) WOOD, A. M. A Textbook of Sound. New York, 1930, Macmillan, 519 p.

THE EXCRETORY SYSTEM AS A METHOD OF CLASSIFICATION OF DIGENETIC TREMATODES

By ERNEST CARROLL FAUST

Parasitology Laboratory, Department of Tropical Medicine, Tulane University

INTRODUCTION

THE earliest investigators who attempted to develop a system of classification for the trematodes were ignorant of the internal structure or life cycles of these organisms. They were therefore unable to discern any fundamental differences between monogenetic and digenetic forms, but were dependent solely on external characters. Thus Zeder (1800) recognized three genera, (1) MONOSTOMATA, "which have a sucker on the venter in addition to one at the anterior end," and (3) POLYSTOMATA, "which have more than one sucker at the anterior end." It is not necessary to point out that Zeder was in error in believing that the acetabula of the polystomes are "anterior" in position, since they are found at the aboral end of the worm.

While Rudolphi's classification (1808) was somewhat of an improvement on that of Goeze (1782), Schrank (1788) and Zeder (l.c.), it left much to be desired. In 1858 van Beneden distinguished between the MONOGENEA and the DIGENEA on the basis of their ectoparasitic and endoparasitic habits. Meanwhile several Continental students, including Nitzsch (1817), von Nordmann (1832), Steenstrup (1842), La Valette St. George (1855), de Filippi (1857) and Pagenstecher (1857) were working on the generations of the digenetic species in snails and prognosticating on their relationship to the adult worms found parasitic in vertebrate hosts. The epochal discovery of Leuckart (1882) and of Thomas (1883), concerning the life cycle of the sheep liver fluke, *Fasciola hepatica*, established the fundamental difference between monogenetic and digenetic groups. Likewise, the study of internal organs of these parasites by various workers revealed the marked variations in the primary and secondary genital organs which existed among species of both groups, and this led Leuckart (1863, 1886) and his students to utilize these organs as a basis of classification. The contributions of Brandes, Braun, Looss, Lühe, Odhner, Ward and other distinguished investigators in this group are too well recognized to require detailed citation. However, Looss deserves special mention, not only because of the contributions which he has made to the system of classification but also for the great numbers of new species which he has added to the group of digenetic trematodes.

Within the past two decades it has become evident that the many thousands of described species of trematodes do not fit into the simpler classification of the earlier workers. New suborders, superfamilies, families and subfamilies have therefore been created to care for this great assemblage of species. The difficulty has been particularly evident in the group of the distomes, where many hundreds of species had been previously "dumped" into the genus *Distomum*. However, it was soon realized that species, which were

grouped together on the basis of similarity of their genital organs, might differ markedly in their other fundamental organs. In certain groups convergent evolution has resulted in the development of similar reproductive organs in species which actually belong to fundamentally different families and even superfamilies. Furthermore, many species fail to "fit" into any of the family groups which have been created, and certain workers have become convinced that the entire scheme required analysis to determine if some more fundamental classification might not be found.

In the meantime a system of classification of the cercaria, based on the characters of this larval stage, has developed practically independently of the older classification of adult forms. (*Vide* Lühe, 1909).

THE EXCRETORY SYSTEM AS A BASIS OF CLASSIFICATION

In his studies both of the adult and larval forms of several species of digenetic trematodes Looss described the excretory system of the organism, indicating the relationship of solenocytes, capillaries, collecting tubules and excretory bladder to one another. However, he apparently did not conceive of the potential importance of these organs as a fundamental basis for classification. Ssinitsin (1905) and Dollfus (1930) have emphasized the significance of the primary collecting tubules as a criterion for determining group relationships, but Cort (1917, 1917a) appears to have been the first to suggest that cercarial larvae and more mature forms, although dissimilar in appearance, might belong to the same groups because of their fundamental solenocyte pattern. Later studies have proved Cort's hypothesis to be correct (Szidat, 1923, 1924; Cort and Brooks, 1928).

Meanwhile a very considerable amount of work has been done on the excretory system in cercariae and some analyses have been made on adult forms. In 1924 the writer published a "synoptic flame-cell formulary for digenetic trematodes." In this scheme the basic and developed formulae for the following cercarial groups and their homologous maritae were presented: notocotylid monostomes, echinostome groups, xiphidiocercariae, gymnophalous and rhopalacercous groups, appendiculate cercariae, cystocercous forms, microcercous forms, cercariaeum species, fork-tailed cercariae, paramphistomate and diplocotylean amphistomes, and the aspidocotylean type. More recent life history contributions on the strigeate species by Szidat (l.c.) and by LaRue and his colleagues; on the plagiorchid forms by McCoy (1929) and by Dubois (1929); on *Opisthorchis* by Verma (1927); on *Bucephalus* by Woodhead (1930); and on *Cryptocotyle* by Stunkard (1929),—all these had added data which are valuable in correlating larvae with adults and adults with one another.

Following LaRue's suggestion (1926) the writer (in 1929) outlined a classification of digenetic trematodes based primarily on the fundamental excretory pattern, but utilizing also life cycle criteria. Among the distomes only those families were included in which there were species parasitic in man. It is now advisable to add to these groups others in which the formulae have been elucidated. The consistent correlation of the two sets of data utilized indicates that the excretory pattern is a natural basis of classification. The information is presented in the following pages.

KEY TO REPRESENTATIVE GROUPS OF DIGENEA, BASED PRIMARILY ON THE SOLENOCYTE PATTERN

CLASS TREMATODA Rudolphi, 1808.

Subclass II. Digenea v. Beneden, 1858.

Almost all species endoparasitic; organs of attachment consisting of one or two suckers, of which the

anterior is always single and median; excretory pores posterior, double in parthenogenetic generations, single in "adult" (marital) individuals; development complex; with alternation of marital and parthenogenetic generations and alternation of hosts.

ORDER I. GASTEROSTOMATA Odhner, 1905.

Mouth on mid-ventral surface; anterior sucker imperforate; intestine a simple sac; flame-cell pattern of the miracidium unknown; expanded formula: $2[(1)^n + (1)^n]$. Maritae usually in intestines of fishes. Example: *Bucephalus elegans* Woodhead, 1930.

FIG. 1

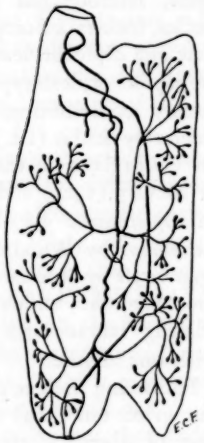

FIG. 2

FIG. 1. EXCRETORY PATTERN IN THE MATURE CERCARIA OF BUCEPHALUS ELEGANS
(After Woodhead)

FIG. 2. EXCRETORY PATTERN IN THE MATURE ASPIDOGASTER CONCHICOLA, SHOWING RIGHT SIDE ONLY
(After Faust)

ORDER II. PROSOSTOMATA Odhner, 1905.

Mouth at or near anterior tip of body, surrounded by oral sucker.

Suborder I. ASPIDOGASTRATA n.n. *pro* ASPIDOCOTYLEA Monticelli, 1892.

Maritae hermaphroditic; oral sucker absent or poorly developed in "adult" worms; ventral sucking organ a powerful adhesive disk or series of small suckers; intestine a simple sac. Flame-cell pattern of the miracidium: $2[1 + 1 + 1]$; expanded formula: $2[(3)^4 + (3)^4 + (3)^4]$. Maritae usually in molluscs but occasionally in lower vertebrates. Example: *Aspidogaster conchicola* v. Baer, 1826.

Note.—Before the time of Monticelli helminthologists regarded this group as monogenetic. Ward (1918) supported the change to the digenetic forms. Since alternation of generations has not been definitely established the matter must be regarded as *sub judice*.

Suborder II. MONOSTOMATA Zeder, 1800.

Maritae hermaphroditic; no ventral sucker present. Flame-cell pattern of the miracidium unknown; expanded formula: $2[(2)^n + (2)^n + (2)^n]$. Maritae in intestinal tract of various groups of vertebrates. Example: *Notocotylus quinqueserialis* Barker and Laughlin, 1911, in American muskrat.

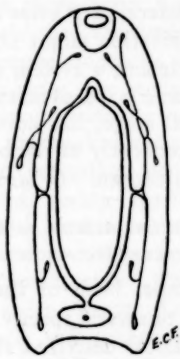

FIG. 3. EXCRETORY PATTERN IN THE MATURE CERCARIA, CERCARIA SPATULA
(After Faust)

Suborder III. STRIGEATA La Rue, 1926.

Maritae monecious or diecious; anterior sucker or attachment organ almost always present; one or more ventral acetabula usually present; cercarial stage with a bifid or forked tail; flame-cell pattern of the miracidium: $2[1 + 1]$; maritae parasitic in gut or blood stream of vertebrates.

Superfamily I. STRIGEOIDEA Railliet, 1919.

Maritae hermaphroditic; body usually divided into two parts, the anterior being flattened, incurved, or cup-shaped, bearing the special organs of attachment, the posterior being more or less cylindrical, ovoid or conical, and containing the major portion of the genitalia; genital pore posterior; eggs operculate or with polar filament; cercariae usually with a true oral sucker and a pharynx; adolescariae (metacercariae) in molluscs, leeches or vertebrates; maritae in vertebrates which feed on the second intermediate host.

TYPE FAMILY: STRIGEIDAE Railliet, 1919.

Flame-cell pattern unknown.

FAMILY II. CYATHOCOTYLIDAE Poche, 1925. Flame-cell pattern: $2[(2) + (2) + (2) + (2) + (2)]$. Example: *Cyathocotyle orientalis* Faust, 1921, with expanded formula: $2[(2)^6 + (2)^5 + (2)^5 + (2)^5 + (2)^5]$.

FAMILY III. ALARIIDAE Tubangui, 1922. Flame-cell pattern similar. Example: *Agamodistomum marcianae* La Rue, 1917, with expanded formula: $2[(6+6)+(6+6)+(6+6)+(6+6)+(6+6)]$.

Note:—According to Dubois (1929) the genus Diplostomum (Proalaria) and related forms have the flame-cell formula: $2[(2 + 2 + 2) + (2 + 2 + 2)]$.

FIG. 4

FIG. 5

FIG. 4. (LEFT). EXCRETORY PATTERN OF MATURING CYATHOCOTYLE ORIENTALIS, SHOWING LEFT SIDE ONLY
(After Faust)

FIG. 5. (RIGHT). EXCRETORY PATTERN OF RIGHT HALF OF AGAMODISTOMUM MARCIANAE
(After Cort and Brooks)

Superfamily II. SCHISTOSOMATOIDEA.
Stiles and Hassall, 1926.

Maritae monecious or diecious, blood-inhabiting flukes, without pharynx, with or without anterior and ventral acetabula; eggs non-operculate; cercariae apharyngeal, with anterior sucker preoral in position, specialized as an organ of penetration; no encysted adolescarial stage; cercariae on emerging from molluscan host enter definitive host through skin.

TYPE FAMILY: SCHISTOSOMATIDAE Looss, 1899.

Sexes separate; anterior and ventral acetabula present; intestinal ceca reunite posteriorly to form a single stem; parasitic in hepatic portal blood of mammals and birds. Examples: *Schistosoma haematobium* (Bilharz, 1852); *S. japonicum* Katsurada, 1904; *S. mansoni* Sambon, 1907, with expanded formula: $2[(2)^n + (2)^n]$; and *Schistosomatium pathlocopticum* Tanabe, 1923, with expanded formula: $2[(3)^n + (3)^n]$.

Suborder IV. AMPHISTOMATA (Rud., 1801) Bojanus, 1817.

Maritae hermaphroditic; acetabulum highly developed, terminal or subterminal and posterior to the reproductive organs; with or without a ventral pouch or disk; eggs operculate; flame-cell pattern of the miracidium: $2[1]$.

SUPERFAMILY PARAMPHISTOMATOIDEA Stiles and Goldberger, 1910.

Maritae with acetabulum caudo-terminal or subterminal; oral sucker and esophagus present; genital pore pre-equatorial; testes one or two, usually preovarial; vitellaria paired or unpaired.

FIG. 6

FIG. 7

FIG. 6. (LEFT). EXCRETORY PATTERN OF THE MATURE CERCARIA OF SCHISTOSOMA JAPONICUM
(After Cort)

FIG. 7. (RIGHT). EXCRETORY PATTERN OF THE MATURE CERCARIA OF SCHISTOSOMATIUM PATHLOCOPTICUM
(After Tanabe)

TYPE FAMILY: PARAMPHISTOMATIDAE (Fischoeder, 1901).

Stiles and Goldberger, 1910.

Maritae without a ventral pouch. Example: *Cercaria convoluta* Faust, 1919, with the formula: $2[(2)^3 + 1 + (2)^4]$.

FAMILY II. GASTRODISCIDAE Stiles and Goldberger, 1910. Flame-cell formula unknown.

FAMILY III. GASTROTHYLACIDAE Stiles and Goldberger, 1910. Flame-cell formula unknown.

Suborder V. DISTOMATA Zeder, 1800.

Maritae hermaphroditic; oral and ventral suckers present; reproductive organs completely or largely posterior to ventral sucker; flame-cell pattern of the miracidium: 2[1]. This suborder contains many hundreds of species, which have been more or less satisfactorily placed in family groups. Some of the superfamily groups, for which the flame-cell pattern has been worked out, are included in this outline.

SUPERFAMILY I. FASCIOLOIDEA Stiles and Goldberger, 1910, *Emend.*

Medium to large flukes, producing large operculate eggs, which are oviposited in the early stages of segmentation. Miracidia developing and hatching in water; with X-type pigmented eye-spots; metamorphosing into sporocysts with or without cecum. Typically two or more generations of rediae. Cercariae large, robust, active, with simple tail; provided with abundant cystogenous material; encysting on vegetation or in fishes, which, when consumed by the definitive host, provide a means of transfer for the adolescariae and for their development into mature worms. Excretory bladder primitively Y-shaped; lateral twigs and capillaries with terminal flame-cells derived from an anterior and a posterior branch of the paired secondary collecting tubules; bladder and primary tubules frequently filled with excretory granules. Fundamental flame-cell pattern of marita: 2[(1 + 1) + (1 + 1)]. Maritae in small intestine and biliary passages of mammals. The superfamily consists of two families, FASCIOLIDAE Railliet, 1895 *sensu stricto* and BRACHYCLADIIDAE Faust, 1929.

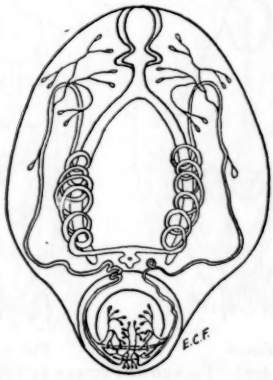

FIG. 8. EXCRETORY PATTERN OF THE MATURE CERCARIA, CERCARIA CONVOLUTA
(After Faust)

I. TYPE FAMILY: FASCIOLIDAE Railliet, 1895.

Eggs very large, ellipsoidal, with thin shells; miracidia bilaterally symmetrical; cercariae encysting on grass or roots of plants in moist meadows. Maritae large, more or less flattened distomes, with elongate excretory bladder reaching nearly to the ovarian plane and with an abundant supply of lateral twigs and capillaries supplying the entire body; with ovary and testes greatly branched; with a short uterus, entirely in front of the ovary. Examples: *Fasciola hepatica* (Linn., 1758); *F. gigantica* Cobbold, 1855; *F. jacksoni* (Cobbold, 1869); and *Fasciolopsis buski* (Lankester, 1857).

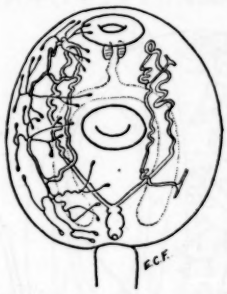

FIG. 9. EXCRETORY PATTERN OF THE MATURE CERCARIA OF FASCIOLA
(After Faust)

II. FAMILY BRACHYCLADIIDAE Faust, 1929.

Flame-cell formula unknown.

Superfamily II. ECHINOSTOMATOIDEA Faust, 1929.

Elongate, moderate-sized flukes, producing relatively large eggs with small opercular cap, and with embryos in early stage of development when oviposited. Miracidia with median eye-spot; developing in water; probably metamorphosing directly into first generation rediae. Cercariae produced in second generation rediae; with simple or marginally-fluted unbranched tails; typically with the number and arrangement of collar spines of the maritae; encysting in their molluscan intermediate hosts, other invertebrates or vertebrates, or on vegetation, which, when consumed by the definitive host provide a means of transfer for the adolescariae and for their development into mature worms. Excretory bladder a pouch-like structure, sometimes coiled back and forth, extending anteriad to the posterior limit of the posterior testis, where it receives the primary collecting tubules; lateral twigs and capillaries with terminal flame-cells derived from secondary and/or tertiary

collecting tubules, which are characteristically filled with excretory granules. Fundamental flame-cell pattern of marita: $2[(3)^n + (3)^n]$, or possibly $2[(2)^n + (2)^n]$. Maritae in intestinal tract of vertebrates. The species of this large and inadequately studied group are at present all placed in the TYPE FAMILY ECHINOSTOMATIDAE Looss, 1902.

TYPE FAMILY: ECHINOSTOMATIDAE
Looss, 1902.

This has the characteristics of the superfamily. Of the five or more subfamilies which have been created for species of this family the life cycle of only one species is completely known, although nearly a hundred cercariae of this group have been described, several with an analyzed flame-cell pattern. This species (*Echinostoma revolutum*) belongs to the

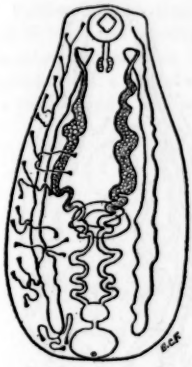

FIG. 10

FIG. 11

FIG. 10. EXCRETORY PATTERN OF THE CERCARIA OF ECHINOSTOMA REVOLUTUM
(After Johnston)

FIG. 11. EXCRETORY PATTERN IN THE ADULT DICROCOELIUM
(After Faust)

Subfamily I. ECHINOSTOMATINAE Looss, 1899.

Collar united ventrally by a ridge; cirrus sac not reaching posteriad beyond equator of acetabulum. Example: *Echinostoma revolutum* (Froelich, 1802), with a flame-cell pattern: $2[(3 + 3 + 3 + 3)^n + (3 + 3 + 3 + 3)^n]$.

Superfamily III. DICROCOELIOIDEA Faust, 1929.

Small to moderate-sized flukes, flattened or cylindrical, producing small to medium-sized eggs, with rather heavy opercular cap, and with embryos fully developed when oviposited. Miracidia metamorphosing in the molluscan host into sporocysts. Xiphidiocercariae with unbranched tails produced in second generation sporocysts; encysting in insect intermediate hosts or on vegetation, which, when consumed by the definitive host provide a means of transfer for the adolescariae and for their development into mature worms. Excretory bladder Y-shaped, with relatively long stem; lateral twigs and capillaries with terminal flame-cells arising directly from the lateral pair of primary collecting tubules. Fundamental flame-cell pattern of marita: $2[(1 + 1 + 1) + (1 + 1 + 1)]$. This superfamily includes the following families: DIROCOELIIDAE (Looss, 1907); BRACHYCOELIIDAE S. J. Johnston,

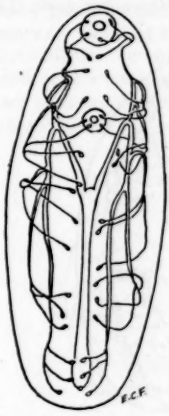

FIG. 12

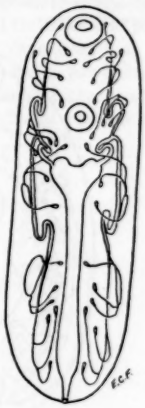

FIG. 13

FIG. 12. (LEFT). EXCRETORY PATTERN OF ADULT GLYPTHELMIS CALIFORNIENSIS
(After Cort)

FIG. 13. (RIGHT). EXCRETORY PATTERN OF ADULT MESOCOELIUM SOCIALE
(After Sewell)

1912; PLAGIORCHIDAE Lühe, 1901, and LISSORCHIDAE Poche, 1926; also ALLOCREADIIDAE Stossich, 1904.

FAMILY I. DICROCOELIIDAE Looss, 1907.

Maritae leaf-like or cylindrical, with testes in front of the ovary. Eggs relatively small, with thickened shoulder into which the operculum fits; miracidia bilaterally symmetrical, without eye-spot; cercariae typical for the superfamily, encysting in or about moist vegetation; maritae in biliary (and occasionally pancreatic) passages of vertebrates. Excretory bladder with a long stem. Fundamental flame-cell pattern of marita: $2[(2 + 2 + 2) + (2 + 2 + 2)]$. Examples: *Dicrocoelium dendriticum* (Rudolphi, 1819)

and many other species of this and closely related genera.

FAMILY II. BRACHYCOELIIDAE
S. J. Johnston, 1912.

Maritae usually cylindrical, with nearly symmetrical testes just behind the ovary in the vicinity of the ventral sucker. Genital pore immediately in front of ventral sucker. Egg shells very thick. Maritae in intestine of Amphibia and Reptilia. Excretory bladder with a relatively long stem. Fundamental flame-cell pattern of marita: $2[(3 + 3 + 3) + (3 + 3 + 3)]$. Examples: *Glypthelmis californiensis* (Cort, 1919), and *Mesocoelium sociale*, (Lühe, 1901) Sewell, 1920.

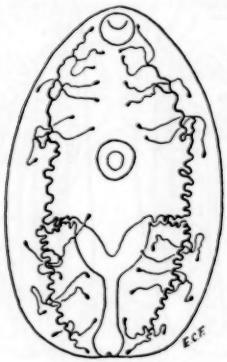

FIG. 14. EXCRETORY PATTERN OF ADULT OPISTHIOGLYPHE ENDOLOBUM
(After Looss)

FAMILY III. PLAGIORCHIDAE Lühe, 1901.

Maritae usually moderately large, oval, seldom flat in cross-section. Testes spherical or lobate, side by side or in tandem. Genital sucker some distance in front of ventral sucker. Eggs numerous and thin-shelled. In intestine of fishes, Amphibia, Reptilia and birds, and in the oral cavity and lungs of Amphibia and Reptilia. Excretory bladder with a stem considerably longer than the branches. Fundamental flame-cell formula: $2[(3 + 3 + 3) + (3 + 3 + 3)]$. Examples (all with the same formula): *Plagiorchis ameiurensis* McCoy, 1928; *Opisthioglyphe endolobum* Looss, 1894; *Haplometra cylindraceum* Looss, 1894; *Dasymetra conferta* (Nicoll, 1911) McCoy, 1928, and *Cercaria hemilophura* (Cort, 1914) McCoy, 1929.

FAMILY IV. LISSORCHIDAE Poche, 1926.

Maritae flattened, moderately elongated. Testes oval in tandem, behind the median lobate ovary, in the posterior half of the body. Genital pore at the left margin of the large acetabulum. In intestine of fresh-water fishes. Excretory bladder with long median stem. Fundamental flame-cell pattern undescribed but undoubtedly having the basic group formula. Only known representative: *Lissorchis fairporti* Magath, 1918.

FAMILY V. ALLOCREADIIDAE Stossich, 1904.

Maritae small to moderate size; body attenuated posteriorly. Testes large, entire or lobate, in tandem series behind ovary. Eggs large, thin-shelled. Cercaria styletted, eye spotted, with a strong, powerful

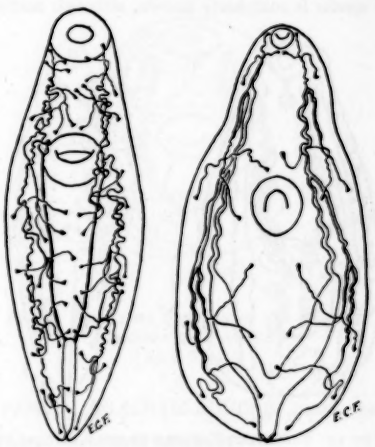

FIG. 15 FIG. 16

FIG. 15. EXCRETORY PATTERN OF AN IMMATURE ALLOCREADIUM ISOPORUM
(After Looss)

FIG. 16. EXCRETORY PATTERN OF THE ADULT HETEROPHYES HETEROPHYES
(After Looss)

caudal appendage; developing in a redia. In intestine of fishes. Excretory bladder with long tubular stem. Fundamental flame-cell pattern: $2[(4 + 4 + 4) + (4 + 4 + 4)]$. Example: *Allocreadium isoporum* (Looss, 1894).

Superfamily IV. HETEROPHYOIDEA Faust, 1929.

Small oval, pyriform or elongate flukes, producing small, rather thick-shelled eggs, having bilaterally symmetrical embryos, which are fully developed when oviposited. Miracidia passively entering the molluscan hosts and metamorphosing into sporocysts. Cercariae developing in rediae; possessing a pair of pigmented eye-spots, as well as marginally-fluted

tails; encysting in animal tissues, which, when consumed by the definitive host, provide a means of transfer for the adolescariae and for their development into the mature worms. Excretory bladder, Y-shaped or V-shaped; lateral twigs and capillaries with terminal flame-cells derived directly from the lateral pair of collecting tubules. Fundamental flame-cell pattern of marita: $2[(1+1)+(1+1)]$. Maritae in the intestinal tract of vertebrates. This superfamily includes the type family HETEROPHYIDAE Odhner, 1914, the family MICROPHALLIDAE Viana, 1924, and possibly the family LECITHODENDRIIDAE Odhner, 1910.

FAMILY I. HETEROPHYIDAE, Odhner, 1914.

Parthenitic generations utilizing species of Melania and Bithynia and possibly other operculate molluscs; cercariae encysting in fresh-water fishes; maritae provided with a genital sucker; living in or attached to the intestinal mucosa of birds and mammals.

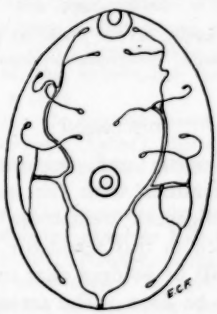

FIG. 17. (LEFT). EXCRETORY PATTERN OF THE ADULT MICROPHALLUS OPACUS
(After Wright)

Fundamental flame-cell pattern of marita: $2[(3+3)+(3+3)]$. Example: *Heterophyes heterophyes* (v. Siebold, 1852).

FAMILY II. MICROPHALLIDAE Viana, 1924.

Maritae minute oval or pear-shaped. Testes in the same plane in posterior portion of body. Muscular penial organ in genital sinus. Maritae in intestine of fishes and birds. Excretory bladder with a short stem and large pouched cornua. Fundamental flame-cell pattern: $2[(2+2)+(2+2)]$. Examples: *Microphallus opacus* (Ward, 1894); *Gymnophallus somateriae* (Levinsen, 1881).

FAMILY III. LECITHODENDRIIDAE Odhner, 1910.

Maritae variable in shape from elongate cylindrical to nearly globular. Testes usually symmetrical, slightly oblique in position at various body levels. Maritae in intestine of insectivorous vertebrates. Excretory bladder V-shaped. Fundamental flame-cell pattern: $2[(3+3)+(3+3)]$; or with the second unit of the anterior group omitted: $2[(3)+(3+3)]$. Examples: *Acanthatrium nycteridis* Faust, 1919, and *Lecithodendrium chefresianum* (Looss, 1896).

Superfamily V. OPISTHORCHOIDEA Faust, 1929.

Flattened transparent leaf-like flukes of moderate size, producing small operculate eggs with thickened shoulder, and containing fully developed embryos when oviposited. Miracidia without eye-spots, secretory glands asymmetrical; metamorphosing into sporocysts in species of BITHYNIIDAE and possibly MELANIIDAE. Cercariae developing in rediae (second generation parthenitae); possessing pigmented eye-spots, well-developed cephalic secretory glands and having marginally-fluted tails, but lacking

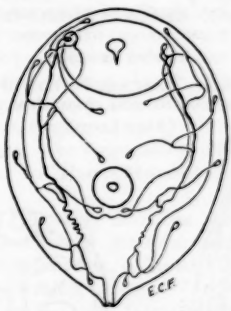

FIG. 18. (RIGHT). EXCRETORY PATTERN OF THE ADULT GYMNOPHALLUS SOMATERIAE
(After Dollfus)

specialized oral spines; encysting in fresh-water fishes, the consumption of which furnishes a means of transfer for the adolescariae to the definitive host. Genital pore of maritae preacetabular, without specialized sucker. Excretory bladder Y-shaped, with unequal arms and with a median S-shaped anterior pouch-like extension; lateral twigs and capillaries with terminal flame-cells derived in one continuous series from the pair of ascending secondary collecting tubules. Fundamental flame-cell pattern of marita: $2[2+2+2+2+2]$. All of the known species belong to the TYPE FAMILY OPISTHORCHIDAE Lühe, 1901.

TYPE FAMILY: OPISTHORCHIDAE Lühe, 1901.

This type family has the characters of the superfamily. The maritae live in the biliary passages

of vertebrates. Example: *Opisthorchis pedicellata* Verma, 1927.

Superfamily VI. TROGLOTREMATOIDEA
Faust, 1929.

Relatively small fleshy ovate flukes, producing moderately large eggs, with a broad opercular cap

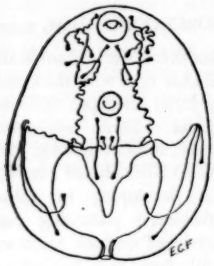

FIG. 19

FIG. 20

FIG. 19. (LEFT). EXCRETORY PATTERN OF THE ADULT ACANTHATRIUM NYCTERIDIS
(After Faust)

FIG. 20. (RIGHT). EXCRETORY PATTERN OF THE ADULT LECITHODENDRIUM CHEFRESIANUM
(After Looss)

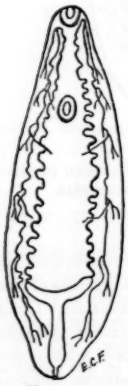

FIG. 21

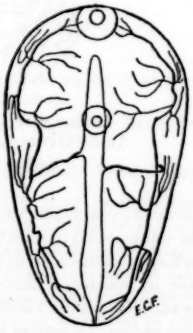

FIG. 22

FIG. 21. EXCRETORY PATTERN OF THE ADULT OPISTHORCHIS PEDICELLATA
(After Verma)

FIG. 22. EXCRETORY PATTERN OF THE IMMATURE PARAGONIMUS WESTERMANI
(After Kobayashi)

and slightly thickened shoulder, and containing embryos in the early stage of development at the time of oviposition. Miracidia without eye-spots, bilaterally symmetrical; utilizing MELANIIDAE and possibly other species of molluscs in which to metamorphose into first generation parthenitae. Cercariae produced in rediae (second generation parthenitae); small, delicate larvae with oral stylet and short, knob-like tail; encysting in arthropods, which, when consumed by the definitive host, afford a means of transfer for the adolescariae. Maritae encysted, typically in pairs, in the respiratory and connective tissues of higher vertebrates. Excretory bladder inverted triangular or with a short posterior shank, at times (in Paragonimus) with a long median tubular pouch arising near the genital pore and extending far anteriad; lateral twigs and capillaries with terminal flame-cells derived directly from the lateral pair of primary collecting tubules. Fundamental flame-cell formula of marita: $2[(3+\ 3+3\ +\ 3+3)\ +\ (3+3\ +\ 3+3\ +\ 3)]$. The few known species belong to the type family TROGLOTREMATIDAE Odhner, 1914.

TYPE FAMILY: TROGLOTREMATIDAE
Odhner, 1914.

This type family has the characters of the superfamily. Example: *Paragonimus westermani* (Kerbert, 1878).

DISCUSSION

To zoologists and helminthologists, who are familiar with the hundreds of genera of digenetic trematodes which are not included in this schematic classification, it will be evident that much work remains to be done. The arrangement of such genera into natural groups on the basis of their excretory patterns, as well as the removal of many genera at present artificially placed in certain family groups, will require concerted and prolonged study. Students of the life cycles of these genera, who utilize the excretory system as a clue to group relationships, will not only facilitate their own work but will provide data for assembling natural groups at present unsuspected.

Certain genera such as *Phyllodistomum*, at present placed in the family GORGODERIDAE, and *Asymphylodora*, an apparent foundling, have known excretory patterns but cannot be allocated because they stand alone in their formula groupings. The same condition now exists in the cases

of some fifty or more cercariae. On the other hand evidence now points to the view that *Anchitrema sanguineum* (Sonsino, 1894) can no longer remain in the family LECITHODENDRIIDAE, and similarly *Cryptocotyle lingua* (Creplin, 1825) cannot be retained in the family HETEROPHYIDAE, because their fundamental excretory patterns are "misfits."

Admittedly the present moment is one of considerable controversy over the wisdom of the scheme proposed, but the system has already justified itself not only in the minds of those who have fostered it from its beginning, but in the hands of younger workers who have utilized it as a means for elucidating most important life history problems.

LIST OF LITERATURE

VAN BENEDEN, P. J. 1858. Mémoire sur les Vers Intestinaux. 376 pp. Paris.

BRANDES, G. 1888. Die Familie der Holostomeae. 72 pp. Leipzig.

———. 1890. Die Familie der Holostomiden. Zool. Jahrb. Abt. Syst., *5*, 549–604.

BRAUN, M. 1889. 1900. Vermes in Bronn's Klassen u. Ordnung d. Thier-Reichs, pp. 209–1731.

CORT, W. W. 1917. Homologies of the excretory system of the forked-tailed cercaria. Jour. Parasit., *4*, 49–57.

———. 1917a. The excretory system of *Agamodistomum marcianae* (LaRue), the agamodistome stage of a forked-tailed cercaria. *Ibid.*, *4*, 130–134.

———. 1919. The cercaria of the Japanese blood fluke, *Schistosoma japonicum* Katsurada. Univ. Calif. Pub. Zool., Berkeley, *19*, 283–298.

CORT, W. W., and BROOKS, S. T. 1928. Studies on the holostome cercariae from Douglas Lake, Michigan. Trans. Am. Micr. Soc., *47*, 179–221.

DOLLFUS, R. 1912. Metacercaire *Gymnophallus somateriae* (Levinsen) var. *strigatus* M. V. Lebour sp. parasite de *Donax vittatus* da Costa. Mem. Soc. Zool. d. France, *25*.

———. 1930. Le point d'aboutissement des canaux collecteurs à la vessie des distomes; son importance au point de vue systématique. Ann. Parasitol., *8*, 143–146.

DUBOIS, G. 1929. Les cercaires de la région de Neuchâtel. Bull. Soc. neuchâteloise des Sciences nat., *53*, 1–177.

FAUST, E. C. 1919. The excretory system in Digenea. I. Notes on the excretory system of an Amphistome, *Cercaria convoluta* nov. spec. Biol. Bull., *36*, 315–321.

———. 1919a. The excretory system in Digenea. III. Notes on the excretory system in a monostome larva, *Cercaria spatula* nov. spec. Biol. Bull., *36*, 340–344.

———. 1919b. A new trematode, *Acanthatrium nycteridis* nov. gen., nov. spec., from the little brown bat. Tran. Am. Micr. Soc., 38, 209–215.

FAUST, E. C. 1921. Phases in the life history of a holostome, *Cyathocotyle orientalis* nov. spec. Jour. Parasit., *81*, 78–85.

———. 1922. Notes on the excretory system in *Aspidogaster conchicola*. Trans. Am. Micr. Soc., *41*, 113–117.

———. 1924. Notes on larval flukes from China. II. Studies on some larval flukes from the Central and South Coast Provinces of China. Am. Jour. Hyg., *4*, 241–301.

———. 1929. The Trematodes or Flukes. Classification. In "Human Helminthology." Phila. 616 pp.

DE FILIPPI, F. 1857. Deuxième mémoire pour servir à l'histoire génétique des trematodes. Mem. r. Acad. d. sc. di Torino. 2 ser. *16* (Cl. d. sc. fis. e mat.), 419–442.

GOEZE, J. A. E. 1782. Versuch einer Naturgeschichte der Eingeweidewürmer thierischer Körper. 471 pp. Blankenburg.

JOHNSON, J. C. 1920. The life cycle of *Echinostoma revolutum* (Froehlich). Univ. Calif. Pub. Zool., Berkeley, *19*, 335–388.

KOBAYASHI, H. 1919. Studies on the lung-fluke in Korea. II. Structure of the adult worm. Mitt. Med. Hochschule zu Keijo. 21 pp.

LARUE, G. R. 1926. Studies on the trematode family Strigeidae (Holostomidae). III. Relationships. Trans. Am. Micr. Soc., *45*, 265–278.

VON LAVALETTE ST. GEORGE, A. J. H. 1855. Symbolae ad Trematodum Evolutionis Historiam. 38 pp. Berolini.

LEUCKART, K. G. F. R. 1863. Die menschlichen Parasiten. I. 766 pp. Leipzig & Heidelberg.

———. 1882. Zur Entwickelungsgeschichte des Leberegels (*Distomum hepaticum*). Arch. f. Naturg., Berlin, *48* (1), 80–119.

———. 1886. Die Parasiten des Menschen. 2 Aufl. 855 pp. Leipzig & Heidelberg.

Looss, A. 1894. Die Distomen unserer Fische and Frösche. Biblioth. zool., Heft 16. 296 pp. Stuttgart.

———. 1894a. Ueber den Bau von *Distomum heterophyes* und *Distomum fraternum* n. sp. 59 pp. Cassell.

———. 1896. Recherches sur la faune parasitaire de l'Egypte. Mem. d l'Inst. egypt. Le Caire, *3*, 1–252.

———. 1899. Weitere Beiträge zur Kenntniss der Trematoden Fauna Aegyptens, zugleich Versuch einer natürlichen Gliederung des Genus Distomum Retzius. Zool. Jahrb., Abt. Syst., *12*, 521–784.

———. 1902. Ueber neuen und bekannten Trematoden aus Seeschildkröten. Zool. Jahrb., Abt. Syst., *16*, 411–894.

Lühe, M. 1909. Parasitische Plattwürmer. I. Trematodes. In Brauer's "Die Süsswasserfauna Deutschlands." 217 pp. Jena.

McCoy, O. R. 1928. Life history studies on trematodes from Missouri. Jour. Parasit., *14*, 207–228.

———. 1929. Notes on cercariae from Missouri. Jour. Parasit., *15*, 199–208.

Nitzsch, C. L. 1817. Beitrag zur Infusienkunde, oder Naturbeschreibung der Cerkarien und Bacillarien. N. Schrift. d. naturf. Gesellsch., Halle., *3*, (1).

von Nordmann, A. 1832. Mikrographische Beiträge zur Naturgeschichte der wirbellosen Thiere. I. 118 pp. Berlin.

Odhner, T. 1905. Die Trematoden des arktischen Gebietes. In Römer & Schaudinn's Fauna Arctica, *4* (2), 291–374.

———. 1910. Nordostafrikanische Trematoden. I. Fascioliden. In Results of the Swedish Zoological Expedition to Egypt and the White Nile, 1901. Stockholm. 170 pp.

Pagenstecher, H. A. 1857. Trematodenlarven und Trematoden. 56 pp. Heidelberg.

Poche, F. 1926. Das System der Platodaria. Arch. f. Naturgesch., *91* (A), 1–458.

Rudolphi, C. A. 1808–1810. Entozoorum sive Vermium Intestinalium Historia Naturalis. I, 527 pp.; II, 457 + 386 pp. Amstelaedami.

Schrank, F. v. P. 1788. Verzeichniss der bisher hinlänglich bekannten Eingeweidewürmer, nebst einer Abhandlung über ihre Anverwandtschaften. 116 pp. München.

Sewell, R. B. S. 1920. On *Mesocoelium sociale* (Lühe). Rec. Indian Museum, *19*, (3), 81–95.

———. 1922. Cercariae Indicae. Indian Jour. Med. Research, *10* (Suppl.), 1–370 + iii pp.

Steenstrup, J. J. S. 1842. Ueber den Generationswechsel, oder die Fortpflanzung und Entwickelung durch abwechselende Generationen. 140 pp. Copenhagen.

Ssinitsin, D. T. 1905. Distomes des poissons et des grenoilles des environs de Varsovie. Mem. soc. nat. Varsovie., Biol. *15*, 1–210. (Russian text).

Stunkard, H. W. 1929. The excretory system of Cryptocotyle (Heterophyidae). Jour. Parasit., *15*, 259–266.

———. 1930. An analysis of the methods used in the study of larval trematodes. Parasitol., *22*, 268–273.

Szidat, L. 1923–1924. Beiträge zur Entwickelungsgeschichte der Holostomen. Zool. Anz., *58*, 299–314; *61*, 249–266.

Tanabe, B. 1923. The life history of a new schistosome, *Schistosomatium pathlocopticum* Tanabe, found in experimentally infected mice. Jour. Parasit., *9*, 183–198.

Thomas, A. P. W. 1883. The life history of the liver fluke (*Fasciola hepatica*). Quart. Jour. Micr. Sci., (n.s.) *23*, 99–133.

Verma, S. C. 1927. On a new trematode, *Opisthorchis pedicellata*, sp. nov., from the Indian siluroid fishes *Rita rita* and *Bagarius yarrelli*, with a key to the species of the genus. Rec. Indian Museum, *29* (2), 139–156.

Vogel, H. 1929. Beobachtungen über *Cercaria vitrina* und deren Beziehung zum Lanzettegelproblem. Arch. f. Schiffs-u. Tropenhygiene, *33*, 474–489.

Ward, H. B. 1918. Parasitic Flatworms. In Ward and Whipple's "Fresh-Water Biology." New York. 1111 pp.

Woodhead, A. E. 1929, 1930. Life history studies on the trematode family Bucephalidae. I. Trans. Am. Micr. Soc., *48*, 256–275; II, *ibid.*, *49*, 1–17.

Wright, S. 1912. Notes on the anatomy of the trematode, *Microphallus opacus*. Trans. Am. Micr. Soc., *31*, 167–176.

Zeder, J. G. H. 1800. Erster Nachtrag zur Naturgeschichte der Eingeweidewürmer. 320 pp. Leipzig.

NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *1901 East Madison Street, Baltimore, Maryland, U. S. A.*

BIOCHEMISTRY AND DEVELOPMENT

Being a review of *Chemical Embryology*, by Joseph Needham. Macmillan Co., New York; University Press, Cambridge. $35.00. 9 x 6¼; 3 vols.; XXI + 4 + 2013; 1931.

By George B. Wislocki, Harvard Medical School.

The present work consists of three volumes divided unequally into five parts: Part I—The theory of chemical embryology, pp. 7–38; Part II—The origins of chemical embryology, pp. 41–227; Part III—General chemical embryology, pp. 231–1665; Part IV—Appendices, pp. 1669–1724; and Part V—comprising bibliography and author index, pp. 1725–1970, subject index, pp. 1971–2012, and index animalium, pp. 2012–2015. It is illustrated by 15 plates and contains 293 tables and 532 figures, mostly graphs.

The short first part of the work is a critique of the successive and conflicting biological theories concerning the nature of the development, organization and growth of the ovum. The second part comprises an historical account from antiquity to the present day of the development of the subject of embryology. The third and largest section covers the subject of general chemical embryology, including the unfertilized egg as a physico-chemical system, increase in size and weight, increase in complexity and organization, the respiration and heat production of the embryo, biophysical phenomena in ontogenesis, the energetics and energy-sources of embryonic development, various sections on the metabolism of the embryo (carbohydrates, proteins, nucleins and nitrogenous extractions, fats, lipoids, sterols, cycloses, phosphorus, sulphur, inorganic substances), enzymes in ontogenesis, hormones in ontogenesis, vitamins, pigments, resistance and susceptibility in embryonic life, serology and immunology, biochemistry of the placenta, biochemistry of the placental barrier, biochemistry of the amniotic and allantoic liquids, blood and tissue chemistry of the embryo, hatching and birth. Part three concludes with the epilogemena which presents briefly the author's formulation of the principal concepts of chemical embryology. There are presented tersely some thirty-two provisional generalizations for chemical embryology. The appendices of Part IV contain normal tables of magnitude in embryonic growth, a chemical account of the maturation of the egg-cells, the chemical changes during metamorphosis of insects (by Dorothy Needham), and the development of the plant embryo from a physico-chemical viewpoint (by Muriel Robinson).

The above description gives the briefest possible resumé of the contents of the three volumes. Needham has undoubtedly attempted a prodigious task and has shown a considerable degree of versatility in the handling of the extremely diversified and scattered material necessary for the treatment of his subject. To relate the chemical and embryological data to one another, giving them historical and biological perspective, is an extremely difficult task which he has accomplished to no mean degree and in a manner so as

to make exceedingly readable material. However, the most enduring aspect of his work is doubtless the service he has rendered to biologists in compiling the voluminous and widely scattered literature of chemical embryology. In this he has done a thorough piece of work, as the bibliography of more than two hundred pages bears witness.

There are relatively few people who could evaluate critically all of the diversified angles of the subject which Needham treats. The volumes should be submitted to several rather than to one person to review. For my own part I can judge the quality of the books only by certain chapters which fall within the scope of my own interests. These are more particularly the sections of several hundred pages in the third volume concerning the biochemistry of the placenta and foetal membranes. An examination of these parts may serve perhaps to illustrate the character of the work.

The subject of the biology of the placenta is rather effectively presented. The main fault of the author's method lies perhaps in a tendency to expound rather too freely from collected data. A little more reflection at times would give the text greater merit. Moreover, there is apparent in the author's method too strong a belief in the virtue of graphs. My first point is illustrated by Needham's astonishing argument concerning the intersexed animals known as "free-martins." He says: (p. 1356).

> Riddle was not the only biologist who drew attention to the difficulties caused to viviparous animals by the development of the foetus inside the mother, i.e. in an exclusively female environment. Lillie in 1917 had pointed out that the male foetus had to be protected in some way from the action of the female hormones, and in certain cases where this protection broke down in the cow the intersexed animals known as "freemartins" resulted. If this is the case, what is oestrin doing in the placenta?

Naturally, as any biologist knows, exactly the reverse is true, that if one foetus is male and the other female, the reproductive system of the female is largely suppressed, and certain male organs develop in the female.

My second point about the use of graphs is illustrated in figures 492 and 493, which show the amounts of amniotic and allantoic fluids in the pig and cow respectively. Paton, Watson and Kerr give for the pig only seven observations for allantoic fluid, six for amniotic fluid. To quote these would be all right, but to draw a curve from them shows undue optimism. I happen to be interested in this subject and have made observations in the sow on the amounts of fluid in some five hundred instances. Plotted on paper these data show something quite different. In pigs over 3 cm. crown-rump length the allantoic fluid values are so variable that they cannot be represented by a curve. Similarly the amniotic fluid in pigs over 15 cm. shows a range of variation from 30 to 450 cc. Now pass to figure 493 for the cow and the justification of my criticism will become still more apparent. Here a large number of observations is given and as in my experience with the pig the values for the two fluids very soon begin to scatter. To infer curves from such a multitude of scattered figures becomes unduly optimistic in the reverse direction. Add to this the fact that I have plotted Paton, Watson and Kerr's original figures and find that in figure 493 four of the most aberrant readings have been deleted without comment, then one will see the value of my objection to the overemphasis of graphs. Similar optimism in the construction of curves from scattered observations applies, I believe, to such figures as 265, 273, 274, 287, 312, 337, 495, and 505. There are, moreover, too many trifling inaccuracies in Needham's tabular material. For instance, in Appendix 1, Table 12, the first set of columns should be headed mm. instead of cm. crown-rump length; while in Table 17 in the upper half of the table presumably "crown-rump length" should be used instead of "total length"—at any rate, it is obvious that the mode of expression in the first part disagrees with that in the second part.

The sections dealing with the origin and functions of the amniotic fluid and allantoic fluid strike me as being rather unsatisfactory, because, although they bring together a lot of interesting data, they do not indicate sufficiently in my estimation the avenues along which the solutions of the problems should be sought. Needham writes that among the

more sensible writers was Schröder (p. 1547) who taught what is probably the most correct view, namely that the amniotic liquid is at first a transudate and is afterwards added to by the foetal urine. Further he concludes: (p. 1562)

> On the whole, then, it may be said that the evidence is decidedly in favour of both amniotic liquid and allantoic liquid in mammals being of foetal origin. There is therefore no gap between terrestrial oviparous animals and mammals, and in all cases the foetal cells are the responsible agents. But when it is necessary to go further, and to say exactly how the foetus produces the amniotic liquid and the allantoic liquid, the illumination is not so good, and a definite answer is difficult; the allantoic liquid may without any hesitation be ascribed to the activity of the foetal kidneys, . . . but the origin of amniotic liquid before the kidneys have begun to function is not so clear. The information about the early stages is rather meagre, and we know little of the powers possessed by the Wolffian body in relation to water metabolism. The urogenital system is probably insufficient to account for the amniotic liquid in the early stages; so we have to fall back on the blood-vessels of the embryo and the amniotic epithelium, . . . And it cannot yet be said that the possibility of a maternal contribution to the amniotic liquid in the very early stages is excluded, so that a great deal more work will have to be done before the origin of this "private pond" in mammals is completely clear.

Needham's conclusions in regard to these questions are based almost solely on reasonings along chemical lines. The solution of these problems requires a combination of chemical and comparative morphological observations. The trouble with all discussions and writings on this subject has been that, in spite of the fact that a variety of mammals has been studied, no one has as yet sufficiently correlated the findings with a broader knowledge of the comparative anatomy of the foetal membranes and embryology. Such a correlation has been attempted in regard to the placenta with astonishing illumination. The value of this Needham justly points out in regard to the placenta, but when it comes to the membranes he fails to follow his own instructions.

Amniotic and allantoic fluids have been thought by one or another writer to be derived exclusively or in large part from one of several sources: (1) foetal urine; (2) transudate from foetal vessels; (3) secretion by amniotic epithelium; and (4) transudation from maternal blood. For many writers, however, the argument has revolved around a discussion of the foetal versus the maternal origin of the fluids—an argument into which Needham allows himself to be drawn. Undoubtedly the truth in these matters lies not in a general conclusion of maternal versus foetal origin, but in a statement of facts for a given animal in terms of different periods of foetal growth. For a while yet we must engage our attention on the individual trees before we can gauge the general character of the forest.

To illustrate my meaning and criticism of Needham I shall give some examples. All embryonic cavities—the segmentation cavity, the exocoelome, the amniotic sac, the allantoic sac, and the yolk-sac—contain fluid from their inception, beginning at a time before there is any foetal circulation or foetal kidneys. In the last instance the maternal organism is responsible for the entire growth of the foetus and its adnexa, but this argument is beside the point. In the early stages, before the origin of the foetal circulation and kidneys, the mammalian blastocyst, covered by trophoblast and containing several epithelial-lined cavities, must derive the fluid contained in these cavities from the activity of the enclosing epithelial layers. To look upon these several layers—trophoblast, amniotic and allantoic epithelium—as completely semipermeable to the surrounding maternal fluids runs contrary to our knowledge of living membranes of this character in general. Moreover, such a maternal transudate would have to penetrate two of them in succession. Contrary to Needham's surmise, it seems to me that an exclusively maternal transudate for this stage can be excluded.

Coming now to the next later stage when the foetal kidneys and circulation are established, how do matters stand? Needham says that the allantoic fluid may without any hesitation be ascribed to the activity of the foetal kidneys. Doubtless there is rather substantial evidence based on careful chemical determinations and accurate data on freezing points that in many animals both allantoic and amniotic fluids are rendered hypotonic by a large increment of excretory products from the mesonephros or

kidneys. In neither instance, however, is this the sole source of the fluid. The evidence that the allantoic fluid is not solely a product of the kidneys can be adduced from a study of the sow. Here, as I have observed, the allantoic fluid accumulates so fast (and so consistently, as a large number of observations shows) that between the 10- and 20-mm. crown-rump length stages the allantoic fluid has attained a volume of 80 or 100 cc. By no possible computation can this rapid accumulation be ascribed to the activity of the mesonephros. The fluid in all likelihood is derived directly from the walls of the allantoic sac, pari passu with the development of the foetal circulation. These observations in the pig also question the postulated relationship of the mesonephroi as a determining mechanism in the initial formation or subsequent expansion of the allantois in mammals. In a number of animals certainly the initial growth of the allantois antedates the appearance of the mesonephroi. Much as one may regret it, these data contradict the view to which Needham is partisan of a close causal relationship between mesonephros and allantois in mammals. In lower vertebrates (birds, reptiles) the mesonephros presumably plays a determining rôle. In mammals, however, there are difficulties in the acceptance of the idea. The case of the allantois in the sow is instructive. It illustrates well, I believe, the point that too much weight must not be placed on analogies with avian eggs. The foetal membranes in mammals have doubtless acquired new and important functions which are not susceptible to explanation by applying avian rules to them.

More interesting still is the fact that the sheep and cow, so far as the data go, show no similarity to the sow in the rapid accumulation of allantoic fluid. This illustrates the need of closer study of nearly related forms.

One other example of my thesis may suffice. The question of the maternal origin of amniotic fluid has been generalized upon in the literature with utter disregard for comparative anatomical facts. As has been said, the early blastocyst is well enclosed in epithelial layers which are presumably more than collodion membranes. At a little later stage these layers become vascularized and remain so for a variable length of time in various mammals. Thus a lamina of vascularized foetal tissue intervenes for a variable period between the cavities of the foetal membranes and the uterus. More especially in rodents the amniotic cavity remains on this account practically inaccessible to maternal transudate on account of the intervening vitelline circulation of the visceral layer of the yolk-sac. One cannot credit Needham's statement (p. 1558) that it has recently been shown experimentally that antibodies pass directly from the maternal blood into the amniotic liquid in the case of the rabbit. Moreover, on this reasoning alone it is not surprising that Watson (p. 1554) failed to get regeneration of amniotic fluid after its withdrawal in the rabbit, although the maternal blood-vessels were normal. On the other hand, in many mammals (some ungulates, cetaceans, sloths, carnivores and primates) there is with advancing gestation a more or less complete disappearance of blood-vessels from certain membranous parts of the chorion accompanied to a great extent by complete atrophy or degeneration of the chorionic epithelium making it possible, so far as the morphological nature of the membranes goes, for transudation from the uterus into the amniotic fluid to occur. Indeed, Schauder (1912, Arch. f. Anat. u. physiol. Anat.) has shown that the concrements, so-called hippomanes, in the allantoic sac of the horse are derived from thickened masses of uterine secretion which have penetrated directly into the allantoic cavity and have become encrusted with urinary salts.

This brief discussion, I believe, illustrates Needham's failure to make the most of his opportunity. He has, however, attempted a vast task and can readily be forgiven for not making more use of the morphological side. Nevertheless, his arguments should not contain such a statement as that on p. 1457 in reference to the placenta: "It must be remembered that in the case of the dog and cat, the placenta as shed consists only of the foetal part." The afterbirth of these

animals contains fully as much maternal tissue as that of the rabbit or man. Similarly (p. 1145), from either the morphological or physiological points of view, the statement that the brooding pouch in *Echidna* may be regarded as a uterus located in an unusual position, the epithelium of which would be able to absorb foetal excreta, seems purely fanciful.

One other point regarding the placenta I should like to discuss briefly. In Needham's section on the placental barrier, more particularly the quantitative study of the barrier and the discussion of the unequal balance of blood constituents between maternal and foetal circulations, he does not bring out clearly a point which I consider important and one that at the same time indicates the most advantageous point of departure for future research on the permeability of the placenta. In Table 243, which sums up the present status of the quantitative distribution of chemical substances between mother and foetus, it becomes apparent, if one investigates the subject further, that fully ninety per cent of the observations thus far made have been on blood obtained at parturition. These data give no indication of how matters may be at other stages of gestation, and permit, therefore, of no generalization concerning the nature of the quantitative permeability of the placenta excepting at parturition at which period there are undoubtedly profound changes in the maternal metabolism. The most urgently needed investigations of the placenta are those dealing in a given animal with chemical study of the blood on opposite sides of the barrier throughout the period of gestation. As an example of this type of investigation Snyder and his associates have recently published data for amino-acid N, urea N, total N.P.N., sugar and hemoglobin in the rabbit during the last third of gestation. With the exception of urea N these substances show a marked difference in concentration on the two sides of the barrier and, moreover, blood sugar and hemoglobin approach towards term much more nearly an equal concentration in the foetal and maternal blood. It is obvious from the data of these observers that conditions are different at various times during gestation.

In conclusion I would like to add that the bibliography of Needham's work will be valuable for decades to come. With rare exceptions I find it accurate. Such an exception concerning the observation by Hess of pulsating veins in the placenta of the bat (p. 1457) is disappointing to me. In the bibliography under Hess, W. (p. 1820) one is advised: "Cit. in Schmidt, q. v." Under Schmidtt, D. (p. 1922) one finds a reference to the Centrlbl. f. Gyn. 1924, 48, 489. On consulting this reference it turns out to be written by one Walther Schmitt concerning the circulation of the placenta, but containing no reference to Hess' work.

With all the criticism that may be leveled against it, Needham's work remains an extremely stimulating and useful one.

BRIEF NOTICES

EVOLUTION

L'Évolution des Espèces. *Histoire des Idées Transformistes.*

By Jean Rostand. Librairie Hachette, Paris. 12 francs. $4\frac{3}{4}$ x $7\frac{1}{2}$; 203; 1932 (paper).

This volume is the second of a series of three planned by the author to be when finished "une histoire assez complète de la biologie." The first in the series was entitled *La Formation de l'Être.* The third is to deal with the genesis of life.

The present book is, within its limits as to length, the best history of the development of ideas about organic evolution that has come to our attention in any language. It is written with great intelligence and charm, out of a wide and thorough knowledge. It differs from most such treatises in not stopping with Darwin, but instead coming right on down to date. The essentials of modern genetic research are thus brought into proper relation with the great problems of evolution. One is accustomed to find French discussion of evolution unduly weighted on the Lamarckian side. M. Rostand has avoided this kind of nationalistic exhibitionism. Lamarck's ideas are dealt with as justly and critically as any others. There is a rather brief (four page) but well chosen bibliography. Unfortunately there is no index. We strongly recommend this book to our readers.

Evolution and Theology. *The Problem of Man's Origin.*

By Rev. Ernest C. Messenger. With a Preface by Father Cuthbert Lattey, and an Introduction by Very Rev. Dr. Souvay. Burns, Oates and Washbourne, London. 12s. 6d. $5\frac{3}{8}$ x $8\frac{1}{2}$; xxiv + 313; 1931.

In this erudite work a Roman Catholic reconciler searches the Scriptures and the Fathers of the Church and finds that until the thirteenth century the account in Genesis was generally understood to teach the spontaneous generation of plants and animals. Since this involves the action of secondary causes, he argues that there is nothing in the traditional view inconsistent with the evolution of one species into another. As to the creation of man, he concludes that, while every loyal Catholic must agree that the soul of Adam came directly from God, there is nothing in Scripture or in the authoritative teaching of the Church that disproves the doctrine of the evolution of the human body. The formation of Eve from Adam's rib he compares to the budding of a begonia leaf. Having gone thus far, on the last page of his book he is overcome by an attack of prudence and concludes that it is "on the whole preferable for a Catholic to suspend his judgment on the matter at the present moment, or at least not to give any unqualified assent to the evolutionary hypothesis." The general impression that we carry away from our reading of the book is that the Fathers of the Church knew a good deal about biology that wasn't so.

A Theory of the Formation of Animals. *By W. T. Hillier. John Wright and Sons, Bristol.* 8s. 6d. net. $5\frac{3}{8}$ x $8\frac{1}{2}$; vii + 166; 1932.

The theme of this book is the dual constitution of animals, i.e., that every animal by virtue of its production by two parents receives part of its hereditary characters from the male and part from the female parent. On this assumption, it is alleged that the majority of animals will inherit a more or less normal amount of any one character and the tendency for a species to remain constant is great. New types of animals arise from the fusion of two animals of dissimilar kind. This occurs rarely, and the offspring has small chance of survival unless it differs markedly from both parents and its points of difference confer on it advantageous qualities. It is logical to expect to find some type animals. The author takes two, *Polygordius* and the herring (*Clupea harengus*). These are regarded as animals of rather simple structure in their separate parts, while related to them are many other forms which show modifications of

these same parts. *Polygordius* is first taken up and a chapter devoted to its anatomy and development. The theory of the development of the blastula from four postulated "phantom blastulae" is then presented, the broad point of which is

> . . . . to show that by regarding life as, in part at least, a cyclic succession of changes going on in a cell, or in a system of cells which has an existence independent of others (as a blastula has) we obtain the instruments necessary for our designs—namely a *main axis*, i.e., the diameter of the path which cannot be shortened although any of those about it may be shortened; and the *active meridian*, which is the path of the rapid current of particles. Since the same particles probably never complete a whole cycle of the life-activity of the blastula, the cycle itself may be regarded as an abstract entity . . . . To postulate an abstract design as the controlling influence of developmental changes is practically tantamount to postulating a psychological quality . . . . Although the design may be abstract, yet the basis for it is attributable to the behavior of material particles.

The latter half of the book is concerned with the herring and its skeletal structure. The final chapter discusses, with reference to the herring, possible explanations of the evolution of bones.

PURPOSE IN EVOLUTION. *Riddell Memorial Lectures, Fourth Series. Delivered before the University of Durham at Armstrong College, Newcastle-on-Tyne, on November 4th, 5th, and 6th, 1931.*

By Sir J. Arthur Thomson. Oxford University Press, New York. 75 cents. $5\frac{7}{8}$ x 9; 59; 1932 (paper).

The question of efficient and final causes has puzzled biologists since the days of Aristotle. In some ways an organism is like a machine, yet its structure and behavior serve certain ends. How can these two viewpoints be reconciled? A machine is designed and built by an artificer to serve his ends; its purposiveness depends on an intelligence outside itself. Are we therefore justified in assuming that the purposiveness of living creatures implies a Divine Artificer and is part of a larger purpose which directs all evolution? Sir Arthur Thomson thinks that we are. The orderliness and beauty of nature, the uniqueness of the earth, the fitness of the environment, the mutual dependence of different organisms, the broad current of progressive differentiation and integration, all suggest to him one increasing purpose running through the ages. There are, it is true, disharmonies and difficulties. Mill, James and Huxley have emphasized the ruthlessness and cruelty of nature. This, the author feels, is a one-sided view. The ethical process is not opposed to the cosmic process but is rather its highest stage. Cooperation as well as competition has its survival value. "The higher animals are rich in the rudiments of the primary virtues, such as courage, endurance, affection, and gentleness."

EVOLUTION YESTERDAY AND TODAY.

By Horatio H. Newman. The Williams & Wilkins Co., Baltimore. $1.00. 5 x $7\frac{1}{4}$; x + 171; 1932.

This is an excellent book for the layman, for it deals only with the necessary and evident part of a theory already widely approved. The facts are simply placed before us by telling actual evidence which we know exists, mainly fossils, embryology, blood tests, geographical distribution and biological background. It is all so easily proven that we can smile at the play of ninepins with Biblical theories and wonder how any orthodox could resist the temptation of setting his thinking cap on a bit straighter. This book can be highly recommended to those who wish an intelligent speaking acquaintance with a subject which for them has heretofore been drowned out by needless controversy.

THE EVOLUTION OF HUMAN BEHAVIOR.

By Carl J. Warden. The Macmillan Co., New York. $3.00. $5\frac{5}{8}$ x $8\frac{1}{2}$; ix + 248; 1932.

The title of this book is somewhat misleading. Actually it deals with human evolution in both its structural and its cultural aspects, although the latter is more emphasized than in many works on the subject. The author points out the difficulties in the determination of racial superiority and the dubious character of much of the eugenic propaganda. Alto-

gether, this is a sane and well written book, which may be recommended to the general reader. A bibliography and indexes are included.

QUELQUES APERÇUS SUR L'UTILISATION DE LA CHARPENTE OSSEUSE PAR LES ANIMAUX VERTÉBRÉS.

By Louis Perbal. Gaston Doin et Cie, Paris. 25 francs. $6\frac{1}{4}$ x $9\frac{1}{2}$; 98; 1932 (paper).

The author attempts to reinstate the evolutionary ideas of Lamarck by evidence drawn from the skeleton of vertebrates. The chief point he makes is that in the bony structures of all animals there is a steady progressive adaptation for particular specialized modes of life. The examples, amply illustrated, are interesting as speculation, but leave us unconvinced.

THE EOCENE SIERRA BLANCA LIMESTONE AT THE TYPE LOCALITY IN SANTA BARBARA COUNTY, CALIFORNIA. *Transactions of the San Diego Society of Natural History, Vol. VII, No. 8.*

By Marvin F. Keenan. San Diego Society of Natural History, San Diego. 40 cents. $6\frac{3}{4}$ x $10\frac{1}{8}$; 32; 1932 (paper).

FOSSIL CORALS OF THE GENUS TURBINOLIA FROM THE EOCENE OF CALIFORNIA. *Transactions of the San Diego Society of Natural History, Vol. VII, No. 10.*

By E. H. Quayle. San Diego Society of Natural History, San Diego. 25 cents. $6\frac{3}{4}$ x $10\frac{1}{8}$; 20; 1932 (paper).

GENETICS

CONTRIBUTIONS TO THE GENETICS OF THE DOMESTIC RABBIT. *Carnegie Institution of Washington Publication No. 427.*

By W. E. Castle and Paul B. Sawin. Carnegie Institution of Washington, D. C. $1.00 (paper); $1.50 (cloth). $6\frac{3}{4}$ x 10; 50 + 12 plates; 1932.

This publication contains two papers: 1. English and Dutch Spotting and the Genetics of the Hotot Rabbit, by W. E. Castle. 2. Albino Allelomorphs of the Rabbit with Special Reference to Blue-Eyed Chinchilla and its Variations, by Paul B. Sawin. Castle's paper presents evidence to show that Hotot and the synthetic English-Dutch race are of like genetic constitution. The former race probably arose, as the latter is known to have arisen, by a crossover between the closely linked genes English and White-Dutch in an individual heterozygous for both.

Sawin's paper presents evidence for the existence of at least three different chinchilla allelomorphs, making a total of six allelomorphs in the albino series of the rabbit. Blue eye is characteristic of the darkest chinchilla allelomorph. Two genetic influences are found to be of primary importance in determining eye color in the rabbit; the albino allelomorphs, and independently inherited modifying genes which affect pigmentation only in the iris. The origin of the manifestation "rusty back" is discussed; certain analogies between the inheritance of blue eye in the chinchilla rabbit and in man are indicated; and a new variation, consisting in an increase in the width of the agouti band on the secondary guard hairs and wool hairs, is reported.

DIE RASSENMISCHUNG BEIM MENSCHEN. *Mit gebührender Berücksichtigung analoger Verhältnisse bei Pflanzen und Tieren.*

By Herman Lundborg. Martinus Nijhoff, The Hague. 14 gulden. $6\frac{1}{2}$ x 10; 221 + 5 plates; 1931 (paper).

The author has undertaken the welcome task of giving as complete as possible a survey of the work done and results reached on the question of race crossing and of indicating directions for further successful study. In this book he gives an historical survey from antiquity down to the present day (1931); discusses the methods of investigation and the auxiliary sciences; the concepts of race and the fundamentals of race mixture in the plant and animal world and man; heterosis and

its opposite; plus and minus varieties; domestication; physical characteristics in race crossing; the importance of serological investigation for anthropology and genetics; resistance vs. disease, fertility and mortality of mixed population; physical characteristics; and the relation of race and race-crossing to culture. On the basis of the results obtained in plant and animal breeding he reaches the general conclusion that race-crossing, also in the case of man, is a two edged sword. Crossing of closely related races produces usually good results in physical and psychical respects, while the mixture between races of distant relationship leads usually to unfavorable results. For the furtherance of these studies and investigations the author expects the United States to take the leadership. There is a valuable bibliography of 43 pages.

GENETIC PRINCIPLES IN MEDICINE AND SOCIAL SCIENCE.

By Lancelot Hogben. Alfred A. Knopf, New York. $3.75 net. 5½ x 8½; 230; 1932.

In this book Professor Hogben attempts "to separate the wheat from the tares, to indicate where a sound foundation of accredited data is available, to discuss what methods can be applied to the extremely elusive nature of the material with which the human geneticist deals, and to re-examine some of the biological concepts which have invaded other fields of inquiry in the light of modern advances in experimental genetics." Unfortunately in a number of cases the separation of the wheat from the tares has not been as thorough as one might have desired. Thus, as Haldane points out, the method of Lenz and Hogben for investigating human characters which are believed to be recessive suffers from the defect that the calculation from the observed data of the probability that the child of two heterozygous parents should be recessive involves the expected value of the probability with which the observed value is to be compared.

LIFE OF MENDEL.

By Hugo Iltis. Translated by Eden and Cedar Paul. W. W. Norton and Co., New York. $5.00. 5½ x 8¾; 336; 1932.

Mention has already been made in these pages of the German edition of this translation which appeared in 1924. The author, a native of Brünn where the Augustinian monastery is located in which Mendel spent so many of his days as student, priest and prelate, has been indefatigable in searching all possible sources that could shed light upon the life and work of this famous biologist. Mendel, having no intimates wrote few letters, neither did he keep a diary, and many of his original documents were destroyed before his greatness was recognized. Nevertheless the author has succeeded in giving us very clear pictures of many phases of his life. He includes a discussion of Mendel's experimental work and a history of the rediscovery of his law. The book contains a number of illustrations, diagrams of experimental work, and an index.

DAS RECHTS-LINKS-PROBLEM IM TIERREICH UND BEIM MENSCHEN. *Mit einem Anhang Rechts-Links-Merkmale der Pflanzen.*

By Wilhelm Ludwig. Julius Springer, Berlin. 38 marks (paper); 39.60 marks (cloth). 5⅝ x 8⅝; xi + 496; 1932.

The author proceeds from the fact that in every asymmetric structure two mirror-image forms are possible—he calls them right and left forms—and poses two questions: (1) which form is realized from an asymmetry, the right form or the left, or both side by side in different degrees? and (2) why just one and not the other; how is it possible that the mirror image form sometimes occurs as "inversion," etc.? The summation of the facts and questions concerned with these problems he discusses in this book as the "right-left-problem." A short introduction defining the problem and terminology is followed by a summary of factual material arranged according to animal groups from protozoa to man. The third part contains a discussion of individual problems and an appendix treats the right-left charac-

teristics of plants. About 700 titles comprise the selected bibliography.

EINFÜHRUNG IN DIE MENSCHLICHE ERBLICHKEITSLEHRE UND EUGENIK.

By K. Saller. Julius Springer, Berlin. 24 marks (paper); 25.80 (cloth). $6\frac{3}{4}$ x $10\frac{1}{8}$; v + 307; 1932 (paper).

After a brief introduction into the theories of genetics with especial emphasis on the theory of the gene, the author proceeds to a lengthy discussion of human inheritance from the physical anthropological viewpoint. There is a great deal of interesting material concerning constitutional types, glands of internal secretions, inheritance of disease and physical and mental anomalies. This part of the book has been thoroughly and carefully compiled and should make a useful text. A final section, most of which is not new, is devoted to the biological aspects of population, race mixture and differential fertility.

A TEXTBOOK OF GENETICS.

By Arthur W. Lindsey. The Macmillan Co., New York. $2.75. $5\frac{1}{2}$ x $8\frac{1}{2}$; xvi + 354; 1932.

An excellent elementary text for college and university students. It will enhance the author's reputation as a writer of sound, teachable textbooks. He uses the dubious pedagogic expedient of questions at the end of each chapter with more intelligence than most of those who adopt it.

ESTUDIOS SOBRE LA ESPERMATOGÉNESIS DEL COLEÓPTERO PHYTODECTA VARIABILIS (OL.). *Los Cromosomas en la Mitosis Gonial y en la Reducción Cromosómica.*

By Fernando Galán. Museo Nacional de Ciencias Naturales, Madrid. $6\frac{3}{4}$ x $9\frac{1}{2}$; 41 + 5 plates; 1931 (paper).

A chromosome study of the beetle *Phytodecta variabilis (Ol.)* with special reference to the Y chromosome.

DIE TECHNIK DER BLUTGRUPPENUNTERSUCHUNG FÜR KLINIKER UND GERICHTSÄRZTE. *Nebst Berücksichtigung ihrer Anwendung in der Anthropologie und der Vererbungs- und Konstitutionsforschung. Dritte Auflage.*

By Fritz Schiff. Julius Springer, Berlin. 8.80 marks. $5\frac{1}{4}$ x $8\frac{1}{4}$; viii + 105; 1932 (paper).

The third edition of an excellent and now standard little handbook on blood-grouping. Some revision has been made and the most recent work is mentioned.

GENERAL BIOLOGY

GRUNDZÜGE EINER ALLGEMEINEN BIOLOGIE. *Die Organismen als Gefüge/Getriebe, als Normen und als erlebende Subjekte.*

By Richard Woltereck. Ferdinand Enke, Stuttgart. 40 marks (paper); 43 marks (cloth). $6\frac{1}{4}$ x $9\frac{1}{2}$; xvi + 629; 1932.

This is an attempt at a comprehensive philosophy of the organism, by the distinguished Leipzig zoologist, based primarily on the results of many years of work done in his laboratory on embryological and developmental physiology, race differentiation, heredity and *Gestalt* of various forms. The general position is summed up as follows:

> The general position which the author was forced to take step by step is very unsatisfying from the viewpoint of the desire for a material-causal understanding, which the author himself long accepted. But the comprehension that the organism is not only a structure and machine of a material sort, but also a norm and creature capable of experience, this revealing double insight brings us closer to the inner character, the inner-being of the organism than the most meticulous cytological or chemical-physical analyses.
>
> For the essence of an organism is not what we observe objectively, but that which it itself experiences from within, no matter if we can or cannot construct an idea concerning this non-spacial "inner," this life in relation to itself. And behind all the "external" and all the non-spacial "inner" of an organism is the non-spacial-timeless "Law of its Behavior" (Lotze), the co-ordinated "Wenn/So" constants which determine the totality of its being.
>
> Looked at in this manner, biology, which among mechanists should form only a specialized part of physical-chemistry, becomes an autonomous fundamental science of life and experience.

LA SPÉCIFICITÉ BIOLOGIQUE. (*Anaphylaxie. Immunité. Hérédité*).

By M. Martiny, H. Pretet and A. Berne. Masson et Cie, Paris. 35 francs. 6¼ x 9¼; vi + 209; 1932 (paper).

The conclusions regarding specificity are not as novel as the physical concepts upon which they rest. It is impossible to do justice to so ingenious a system of physical chemistry in a few words. We are introduced to four kinds of ether, electromagnetic, biological, gravitational, and psychic; to a theory of matter in which a hydrogen atom is composed of 1846 electrons, themselves aggregates of ether particles; and to a system of interaction of organized bodies by means of radiations transmitted by the appropriate ether. Thus, an antibody, which is thought of as the union of antigen and a globulin, emits radiation of the same frequency as the antigen, and should the two be brought into proximity antigen and antibody will enter a condition of resonance and precipitate. That's about all there is to immunity, and heredity isn't much more difficult to explain.

HUNTING.

By Edith M. Patch and Harrison E. Howe. The Macmillan Co., New York. $.80. 5¼ x 7¼; viii + 161; 1932.

OUTDOOR VISITS.

By Edith M. Patch and Harrison E. Howe. The Macmillan Co., New York. $.80. 5¼ x 7¼; xi + 212; 1932.

Manifestations of nature found in the out-of-doors environment of every child compose the subject matter of these delightful books for the very young reader. *Hunting* focusses the attention of the child on holes—of ant, squirrel, woodpecker, woodchuck, etc., and on animal and plant life that can be found in school gardens, in parks and at the zoo. *Outdoor Visits* can be made in all four seasons. What any child can see in fall, winter, spring and summer is described by narrating what the two children in the book see in their outdoor life during a year. The books will not only hold the child's interest while he reads them, but will awaken and stimulate his awareness of the world of reality which surrounds him.

GROWTH AND THE DEVELOPMENT OF MUTTON QUALITIES IN THE SHEEP. *A Survey of the Problems Involved in Meat Production. By John Hammond, with a Section in Conjunction with A. B. Appleton. Oliver and Boyd, Edinburgh and London.* 42 shillings net. 6 x 9¾; xxvi + 597; 1932.

This is an extensive survey of the scientific principles involved in the production of meat from the physiological, anatomical and practical point of view. The authors' method of starting their investigations with the product (meat) and working backward to find out what conditions and factors have affected its formation has yielded interesting and valuable results. The work is divided into five sections, as follows: The rate of growth in live weight in a flock of Suffolk sheep; the carcase percentage and the relative development of the different organs in the body; variations in the rate of development of different parts of the skeleton (body conformation); variations in the proportions of muscle, fat and bone in the carcase; and study of the leg of mutton. Each section concludes with a lengthy list of references. In the text are numerous tables, diagrams and figures while in a series of appendices will be found detailed growth data. There are author and subject indices.

BIOLOGIE DES RADIUMS UND DER RADIOAKTIVEN ELEMENTE. *Erster Band: Biologie des Radiums und Uraniums.*

By Julius Stoklasa in collaboration with Josef Pěnkava. Paul Parey, Berlin. 74 marks. 6½ x 9½; xiv + 958; 1932.

The authors of this book have undertaken a colossal task. Besides presenting the results of their own investigations on radium and radioactive elements they aim to give the first complete summary of the work of all other investigators in this field. This first volume deals with the radioactivity of the atmosphere, lithosphere, and hydrosphere; the influence of radioactivity on bacteria, plants and animals and the biology of uranium and the ionium-radium family. The second and last volume will contain chapters on the following: the biology of ionium, radium A, B, C, D, E, and F, lead, the

actinium and thorium families, calcium and rubidium, the practical applications of radium and the radioactive elements in plant and animal production and in medical therapy. There are author and subject indices and lists of literature are appended to most of the chapters.

REGENERATION UND TRANSPLANTATION. *II. Band, 2. Teil: Transplantation unter Berücksichtigung der Explantation, Pflanzenpfropfung und Parabiose.*

By E. Korschelt. Gebrüder Borntraeger, Berlin. 72 marks (paper); 75 marks (cloth). $6\frac{1}{2}$ x 10; 697–1559; 1932.

The first part of the second volume has already been reviewed in Volume VII, page 226, of this journal. This is the last section of the work, and deals with the more difficult and complicated transplantations. Successively they are skin, sense organ, nervous system, skeletal system, muscle, tendon and fascia, connective tissue, fat tissue and peritoneum, circulatory system and various internal organs, gonads; transplantations in the amphibians, birds, and mammals; embryonal and tumoral transplantations. There is an exceptionally good chapter on organization centers and factors.

The author has covered a great mass of literature in this volume, very thoroughly and carefully. The whole treatise, now that it is complete, will be an invaluable reference source.

THE LAST CRUISE OF THE CARNEGIE.

By J. Harland Paul. The Williams and Wilkins Co., Baltimore. $5.00. 6 x 9; xvii + 331; 1932.

This is a narrative of the seventh cruise of the *Carnegie*—the non-magnetic ship built by the Carnegie Institution of Washington to obtain magnetic and electric data over the oceans—which ended tragically in the burning of the vessel and the death of Captain Ault. The program of this cruise also included the study of the physical, chemical and biological conditions of the ocean-depths. The reader will find it a fascinating account of distant places and peoples and of the difficulties of oceanographic research.

METHUSALEME DER TIERWELT. *Studien über die optimale Lebensdauer.*

By Josef Kluger. Josef Kluger, Wünschelburg Heuscheuer. 50 cents. $5\frac{5}{8}$ x $8\frac{3}{4}$; 49; 1931 (paper).

Following a short general discussion of the problem of optimal duration of life and limits of size, the author presents accounts of the pike of Kaiserslautern which, it is claimed, attained an age of 267 years and a weight of 350 pounds; the carp of Bischofshausen which is reputed to have been about 200 years of age and had a weight of 70 pounds, and length of 183 cm. when caught; and other longevous giants among fish, snails and other animals. The bibliography of 65 titles includes only references not given in the well known studies on longevity.

THE ESSENTIALS OF BIOLOGY.

By James Johnstone. Longmans, Green and Co., New York. $4.50. $5\frac{3}{8}$ x $8\frac{1}{2}$; xv + 328; 1932.

The field of zoölogical research has been pretty thoroughly worked over, Prof. Johnstone believes, and an introduction of new concepts of physics is necessary to make it productive again. It is therefore an opportune time to summarize the results which have been obtained with the help of Newtonian physics. His survey is better suited for philosophers than for biologists.

ANIMAL LIFE AND SOCIAL GROWTH.

By Warder C. Allee. The Williams and Wilkins Co., Baltimore. $1.00. 5 x $7\frac{1}{4}$; xii + 159; 1932.

This little introduction to animal ecology is very well suited to the large group of people, untrained in biology, who take a lively interest in natural history.

HUMAN BIOLOGY

ROME AND THE ROMANS. *A Survey and Interpretation.*

By Grant Showerman. The Macmillan Co., New York. $5.00. $5\frac{1}{8}$ x $7\frac{3}{4}$; xxi + 643; 1932.

While Professor Showerman has written this primarily for high school and college boys and girls, it will find many interested readers among adults. The purpose of the book is humanistic. "It aims to assemble, not all facts, but significant facts; to present information which will add not only to knowledge but to the meaning of life; to make learning readable and reasonable." He surveys all the significant steps in the growth of the great Roman civilization and traces the influence which this great culture has had in molding the present Western civilizations. In the concluding chapter of his book he says: "Rome is the one city on earth in which both the present and the past are still authoritative. It is the one spot on the earth whither the pilgrim from Europe and the Americas may fare as to the center and the source of the culture in which he is bred, feeling that 'its importance in universal history it can never lose. For into it all the life of the ancient world was gathered: out of it all the life of the modern world arose.'"

The volume is abundantly illustrated, has sections on chronology, bibliography, and annotations and is well indexed. Altogether it is a fine book, sound in scholarship and delightful in manner.

SPENCER'S SCIENTIFIC CORRESPONDENCE *with Sir. J. G. Frazer and Others.*

Edited by R. R. Marett and T. K. Penniman. Oxford University Press, New York. $3.00. $5\frac{1}{2}$ x $8\frac{1}{2}$; xi + 174; 1932.

This correspondence between Sir Baldwin Spencer and Sir James Frazer, with supplementary letters to Howitt, Fison, Balfour, Marett and others, will be of great value to the historian of anthropology as well as of interest to any lover of that science. Although much of the material has already been published in the various books of Spencer and Frazer, the reader can here follow the process of discovery, can watch the interaction and coöperation between the field and the armchair anthropologist, the facts gathered by the one suggesting to the other new theories of the origin of human institutions, which in turn suggest new subjects for observation.

One of the most interesting of Spencer's discoveries was that among the Australian tribes, as Malinowski later found among the Trobriand Islanders, there was no understanding of the relation between sexual intercourse and the production of children. According to them the latter was purely a question of reincarnation. When the spirit of a dead man wished to return to the land of the living, it entered into a woman and in due time was born. There is one point about this, not touched on in Spencer's account, which puzzles us. If the tribe increased in numbers, of whom were the extra children supposed to be the reincarnation?

MAN AND MEDICINE. *An Introduction to Medical Knowledge.*

By Henry E. Sigerist, with an Introduction by William H. Welch. Translated by Margaret G. Boise. W. W. Norton and Co., New York. $4.00. $5\frac{5}{8}$ x $8\frac{1}{2}$; x + 340; 1932.

In this book one of the most distinguished of medical historians gives to the medical student and the layman a broadly philosophical outline of modern medicine, its historical and cultural background, and its relations to biology and sociology. Beginning with the healthy man, his structure, his functions, and his mind and spirit, the author next considers the sick man and his relation to society, the symptoms of disease, pathology, the causes of disease, medical aid in its three aspects of recognizing, curing and preventing disease, and finally the physician, his professional, economic and social relations. The book is pervaded by that spirit of humane intelligence which should characterize every good physician.

THE CONCEPTS OF SOCIOLOGY. *A Treatise Presenting a Suggested Organization of Sociological Theory in Terms of Its Major Concepts.*
By Earle E. Eubank. D. C. Heath and Co., Boston. $4.80. $5\frac{7}{8}$ x $8\frac{3}{4}$; xvii + 570; 1931.

A sorting out of the various sociological concepts that exist today, put in their proper categories. The arrangement of material under the headings of: I. Societary composition; II. Societary causation; III. Societary change; and IV. Societary products, is forceful and appears logical. The author has made a systematic attempt to present the main points of sociological theory in terms of its basic concepts, and has done the job very well. There is a comprehensive bibliography arranged according to subject headings. This book will make an excellent textbook.

STATISTICAL ANALYSIS OF AMERICAN DIVORCE.
By Alfred Cahen. Columbia University Press, New York. $2.25. $5\frac{3}{4}$ x $8\frac{3}{4}$; 149; 1932.

In this careful study the author concludes that migratory divorce, marriage and divorce legislation, and desire to remarry, play relatively minor rôles in the five-fold increase in the divorce rate since the 60's, that a federal divorce law would be inadvisable, that 63 per cent of the divorced couples in 1928 were childless, and that the increase in divorce is in general an effect of changing social conditions, one of the "costs of progress." A bibliography and an index are appended.

THE MONGOL IN OUR MIDST. *A Study of Man and His Three Faces.*
By F. G. Crookshank. Kegan Paul, Trench, Trubner and Co., London. 21 shillings net. $5\frac{1}{4}$ x 8; xx + 539; 1931.

In rewriting the third edition of his book Dr. Crookshank has replied to criticisms of his theory of human evolution, but in our opinion without making it essentially any more convincing.

QUARTERLY BULLETIN OF THE HEALTH ORGANISATION, LEAGUE OF NATIONS, *Volume I, No. 1.*
American Agents: World Peace Foundation, Boston. Subscription: $2.00 a year; single issues 50 cents. $6\frac{1}{4}$ x $9\frac{1}{2}$; iv + 157 + map; 1932 (paper).

A bulletin to be welcomed as it keeps us informed of the current activities of the Health Organisation of the League.

ZOÖLOGY

MANUAL OF ANIMAL BIOLOGY.
By George A. Baitsell. The Macmillan Co., New York. $2.50. $5\frac{1}{2}$ x $8\frac{1}{2}$; xi + 382; 1932.

The contents of this excellent manual of animal biology are presented in two parts: Part I, Descriptive; and Part II, Laboratory Directions. In Part I, after a general discussion of protoplasm and the structure and life-processes of cells, the various animal forms from the amoeba through the vertebrates are considered. In each case the animal is presented from the point of view, first of structure and then of life-processes and organ systems. The final chapter of Part I is devoted to brief descriptions of the embryology of the frog, chick, and mammal. At the end of each chapter, besides a list of general references, page references to pertinent text-books are given. Part II outlines concise laboratory directions for procedure in studying the various forms. The book is illustrated by a series of full-page drawings of different animals in their natural habitats.

HANDBOOK OF BIRDS OF EASTERN NORTH AMERICA. *With Introductory Chapters on the Study of Birds in Nature.*
By Frank M. Chapman. D. Appleton and Co., New York. $5.00. 5 x $7\frac{5}{8}$; xxxvi + 581; 1932.

In this 1932 edition of Dr. Chapman's excellent handbook important changes appear. It has been completely rearranged and largely rewritten to accord with the revised classification of birds which the American Ornithologists' Union has just completed.

Much new material and many new illustrations have been added and parts of the old text have been deleted. Dr. Chapman has made this a most satisfactory working volume not only for the serious student but for the enthusiastic amateur as well. The first part of the book (100 or more pages) is devoted to methods and suggestions for observing birds. A field key to the commoner eastern land birds has been arranged which the beginner will find of aid in leading him through the first stages of bird study. Over 400 pages are devoted to the detailed classification of birds. The volume is generously illustrated, contains a bibliographical appendix and is indexed.

THE INVERTEBRATA. *A Manual for the Use of Students.*

By L. A. Borradaile and F. A. Potts, with Chapters by L. E. S. Eastham and J. T. Saunders. The University Press, Cambridge; The Macmillan Co., New York. 25 shillings net (England); $5.50 (U.S.A.). 5½ x 8½; xiv + 645; 1932.

An excellent survey of the Invertebrata with ample illustrations and simple and accurate descriptions of the characteristic features of each group. This book is intended for advanced students. It fills adequately a need that has been seriously felt by teachers of zoölogy. It is an interesting fact that this book emanates from an English laboratory, where old fashioned *zoölogy* is still regarded as worthy of being taught. Except in the field of entomology the teaching of zoölogy in this country now rather more largely concerns itself with dilute biochemistry and physiology, concentrated genes and chromosomes, and that brand of philosophy technically called hooey, than with the kinds of animals that inhabit the earth.

LIVES.

By Gustav Eckstein. Harper and Bros., New York. $2.50. 5¾ x 8⅝; 216; 1932.

Gustav Eckstein exhibits in *Lives* the same brilliancy and skill that is to be found in his life of Noguchi. The book consists of short biographical sketches of a pair of white rats that lived in his laboratory desk, a little green parrot and her companion Ab, the canary family that had the freedom of the room, the laboratory cockroaches, Joe the greenhouse man, etc., etc. Various chapters have already appeared in Harpers. The drawings, so the author says, were stolen from Hokusai.

ANIMAL BIOLOGY.

By Lorande L. Woodruff. The Macmillan Co., New York. $3.50. 5½ x 8½; xii + 513; 1932.

Professor Woodruff has made over his "Foundations of Biology" into a textbook of general zoölogy by the omission of certain chapters devoted to plants and by adding more material relating to animals, and especially man. The book is well illustrated and its list of references should lead an inquisitive undergraduate to some interesting reading.

DIE TIERWELT DER NORD- UND OSTSEE. *Lieferung XXI.*

Edited by G. Grimpe and E. Wagler. Akademische Verlagsgesellschaft, Leipzig. 12 marks. 6 x 8½; 132; 1932 (paper).

The present section of this useful survey of the fauna of the North and Baltic seas, previous numbers of which have been noted in these columns, deals with the following subjects: Hydrography, by Bruno Schulz, and Sporozoa, by Eduard Reichenow.

THE SUBGENUS STEGOMYIA IN NETHERLAND INDIA. *Bijblad 2 of the Geneeskundig Tijdschrift voor Nederlandsch-Indië.*

By J. Bonne-Wepster and S. L. Brug. G. Kolff and Co., Batavia, Java. F. 2.50. 6¼ x 9½; 85; 1932.

This excellent monograph deals with the morphology and life history of those species of the subgenus *Stegomyia* found in the Dutch East Indies. *Aedes aegypti* (*Stegomyia fasciata*), the vector of yellow fever and dengue, is treated in especial detail.

THE JOURNAL OF ANIMAL ECOLOGY, *Vol. I, No. 1.*

Edited for the British Ecological Society by Charles Elton and A. D. Middleton. Cambridge University Press, London. Subscriptions (of members) 25s. per annum; (of non-members) 30 s. per annum. Single copy 22s. 6d. net. 7¼ x 10; 100; May 1932.

We welcome this addition to the list of biological journals. Under the able guidance of Mr. Charles Elton its usefulness and success are assured.

GENERAL CATALOGUE OF THE HEMIPTERA. *Fascicle IV. Fulgoroidea. Part I. Tettigometridae.*

By Z. P. Metcalf. Smith College, Northampton, Mass. $1.00. 6 x 9; 69; 1932 (paper).

This catalogue, previous parts of which have been noted in our columns, gives references from the literature, with an indication of the character of the data contained, to the family, its subfamilies, tribes, genera, and species.

FLAGELLATES OF THE GENUS TRICHONYMPHA IN TERMITES. *University of California Publications in Zoölogy, Vol. 37, No. 15.*

By Harold Kirby, Jr. University of California Press, Berkeley. $1.50. 7⅛ x 10¾; 128 + 12 plates; 1932 (paper).

AN UNRECOGNIZED SHREW FROM NEW JERSEY, *by Morris M. Green.* A RELIC SHREW FROM CENTRAL CALIFORNIA. *By Joseph Grinnell. University of California Publications in Zoölogy, Vol. 38, Nos. 7 and 8.*

University of California Press, Berkeley. 25 cents. 7⅛ x 10¾; 4; 1932 (paper).

THREE NEW RODENTS FROM LAVA BEDS OF SOUTHERN NEW MEXICO. *University of California Publications in Zoölogy, Vol. 38, No. 5.*

By Seth B. Benson. University of California Press, Berkeley. 25 cents. 7 x 10¾; 10 + 2 plates; 1932 (paper).

CONTRIBUTIONS TO A KNOWLEDGE OF THE MYSIDACEA OF CALIFORNIA. *I. On a Collection of Mysidae from La Jolla, California, and II. The Mysidacea Collected During the Survey of San Francisco Bay by the U. S. S. "Albatross" in 1914. University of California Publications in Zoölogy, Vol. 37, Nos. 13 and 14.*

By W. M. Tattersall. University of California Press, Berkeley. 50 cents (two numbers in one cover). 7 x 10¾; 47; 1932 (paper).

COCCIDIOSIS OF THE GUINEA PIG. *University of California Publications in Zoölogy, Vol. 37, No. 9.*

By Dora P. Henry. University of California Press, Berkeley. 65 cents. 7 x 10¾; 48 + 4 plates; 1932 (paper).

THE OOCYST WALL IN THE GENUS EIMERIA. OBSERVATIONS ON COCCIDIA OF SMALL MAMMALS IN CALIFORNIA, WITH DESCRIPTIONS OF SEVEN NEW SPECIES. ISOSPORA BUTEONIS SP. NOV. FROM THE HAWK AND OWL, AND NOTES ON ISOSPORA LACAZII (LABBE) IN BIRDS. *University of California Publications in Zoology, Vol. 37, Nos. 10, 11, 12.*

By Dora P. Henry. University of California Press, Berkeley. 50 cents (three numbers in one cover). 7 x 10¾; 32 + 5 plates; 1932 (paper).

BOTANY

A TEXTBOOK OF BOTANY FOR COLLEGE STUDENTS. *Being a Revision and Amplification of "A College Textbook of Botany for First Year Students."*

By David M. Mottier. P. Blakiston's Son and Co., Philadelphia. $4.00 net. 5⅞ x 9; xiii + 601; 1932.

GENERAL BOTANY FOR COLLEGES.

By Ray E. Torrey. The Century Co., New York. $3.50. 5¾ x 8¾; xxii + 449; 1932.

COLLEGE BOTANY.

By William H. Eyster. Ray Long and Richard R. Smith, New York. $3.00. 5½ x 8¼; xvi + 695; 1932.

In recent years there have been several changes in the makeup of elementary botanical textbooks; the more numerous illustrations and diagrams are less frequently borrowed from older textbooks, cytological data are being used to illuminate the life history studies, and ecology and paleobotany are beginning to receive attention. The tendency is to prepare a book which will hold the interest of the average college student rather than an elementary scientific treatise. In these trends these three texts share in greater or less degree.

Professor Mottier's textbook follows the traditional pattern most closely. The most distinctive feature is the section devoted to a survey of the plant kingdom; however, not much is said about evolution.

Professor Torrey has tried to make his textbook represent as nearly as possible the present state of botanical knowledge in order to meet "the needs of the cultured humanist" as well as those of the future botanist. In so doing he has introduced a number of topics not usually found in elementary textbooks, notably sections on ecology, plant anatomy, and paleobotany. It is to be suspected that much of the material presented under the latter two topics will be unfamiliar to many professional botanists. The section of the book devoted to life histories of representatives of different evolutionary stages is especially good. The use of the "triangle of cytology" to show the relation of nuclear phenomena to the alternation of generations is both novel and helpful.

"The writer has felt for a long time the serious need for a more vivid and picturesque presentation of the subject of botany in order that the beginner might be attracted to rather than be repelled by it." In this he has succeeded very well. His book also "seeks to develop the intuitive perception of deeper truths; yet at the same time, it tries to guard against premature and futile speculation—that metaphysical moonshine in which the beginner often loves to wander." In this he has not always been successful.

Professor Eyster's textbook is intended for more mature students than are the other two. The rigors of botanical nomenclature are considerably ameliorated by a generous use of illustrations (there are 565, more than 400 of them original) and by a good glossary. About half the book is devoted to a survey of phylogenetic groups. His treatment of the physiology sections is commendable.

PHYSIOLOGY OF BACTERIA.

By Otto Rahn. P. Blakiston's Son and Co., Philadelphia. $6.00. 5½ x 8½; xiv + 438; 1932.

This important contribution to bacteriological literature is "an attempt to coordinate the various simplest functions of life, to study each function in itself and in its effect upon the other functions." It is "limited to the necessary functions of life; therefore motility, phosphorescence, tropisms, and similar conspicuous but unimportant functions have been omitted." The author believes not only that bacteria should be the starting point in the study of many general physiological problems but that it is only through bacteriological investigations that some of the principles of biology can be found and studied. While he does not review the literature on the subjects which he deals with, he does present all the theories. In each chapter and subchapter is given a summary, usually separated according to facts and theories. The four main sections of the book deal with (1) endogenous catabolism; (2) energy supply of the cell; (3) growth; and (4) mechanism of death. In an appendix he includes a discussion on (i) the size of microörganisms, (ii) multiplication of bacteria, and (iii) the fermenting capacity of the single cell. The text contains 123 tables and 42 figures. There are author and subject indexes.

PLANTS. *What They Are and What They Do. By A. C. Seward. The Macmillan Co., New York.* $1.50. 4⅝ x 7¼; xi + 141; 1932.

Professor Seward is too modest in indicating the scope of his book.

My aim in writing this book is to present a few aspects of plant-life, in language as free as possible from technical terms, to readers who have little or no knowledge of botany or other branches of natural science. The book is not designed for students whose bent has caused them to specialize in science during the later stages of their school career, nor is it based on any examination schedule. The primary purpose is to introduce students whose school work, either by choice or the force of circumstances, is mainly classical or literary to some of the more striking attributes of the humbler organisms in order that they may be in a better position to appreciate what the world owes to plants.

We would suggest that his treatment of the elements of plant physiology is so much better than the usual textbook presentation that it should make good supplementary reading for college students.

CONTRIBUTION À L'ÉTUDE ÉCOLOGIQUE DU BLÉ. *Les Blés Auvergne. Essai sur la culture du Blé et particulièrement des Poulards d'Auvergne dans le Puy-de-Dôme.*

By A. Dusseau. Librairie G. Delauney, Clermont Ferrand, Puy de Dôme. 60 francs. 6½ x 10; 320 + 4 plates; 1931 (paper).

Several features of the Puy-de-Dôme make it a region especially suited to a study of wheat varieties and their growth, yield, and taxonomic characteristics. Within this department wheat has been grown on mountains and plain since Roman times under exceedingly diverse climatic conditions so that an ecological treatment such as this is particularly appropriate. Systematic descriptions of wheat varieties grown in this region date from the sixteenth century, reliable statistics begin early in the eighteenth century, and Mlle. Dusseau has made good use of both. Her own work on the taxonomy of the local varieties and the accompanying biometrical treatment deserves careful attention. Crop statistics for the years 1825, 1909, 1925, and 1926 are given for each of the 49 cantons included in this survey. There is a bibliography of 693 titles.

THE INFLUENCE OF WEATHER ON CROPS: 1900–1930. *A Selected and Annotated Bibliography. United States Department of Agriculture Miscellaneous Publication No. 118.*

By A. M. Hannan. U. S. Government Printing Office, Washington. 40 cents. 5¾ x 9⅛; 245; 1932 (paper).

"This bibliography is mainly concerned with the influence of weather on crops in connection with the germination, growth, development, susceptibility to disease, and final yield. It contains references to laboratory studies, field studies, and statistical studies of the effect of different conditions of temperature, precipitation, humidity, light, and wind on vegetation in many parts of the world. Most forms of vegetation, with the exception of flowers and root crops, have been included." Altogether 2,324 references are listed and annotated. The work is well indexed.

DER GEOTROPISMUS DER PFLANZEN.

By Felix Rawitscher. Gustav Fischer, Jena. 21 marks (paper); 22.50 marks (cloth). 7 x 10; viii + 420; 1932.

This is a book for specialists and its aim is to illuminate the current trends of research on this topic. It is a field where clarity is needed; since 1673 more than 1400 papers have appeared on geotropism and although the external behavior of plants with respect to gravity is rather well understood the internal mechanisms are still a matter for dispute. Few people have any appreciation of the extent to which plant form and function are related to gravity and the scope of this book is broad enough to include most of the types of influence.

MORPHOLOGY

OVOGENESIS AND THE NORMAL FOLLICULAR CYCLE IN ADULT MAMMALIA. *Memoirs of the University of California, Volume 9, No. 3.*

By Herbert McL. Evans and Olive Swezy. University of California, Berkeley. $5.00. 10 x 13⅜; 106 + 18 plates; 1931 (paper).

This investigation on rhythmical changes in the mammalian ovary has yielded interesting results. The mammals studied were the rat, guinea pig, dog, cat, monkey

and man. Unfortunately the findings can be only briefly mentioned.

"Ovogenesis in the rat, guinea pig, dog, cat, and man occurs throughout the whole period of sexual life in a rhythm fundamentally related to the ovulation cycle. In all cases the new birth of eggs occurs in large numbers throughout metoestrum and anoestrum. In the latter phases of this production a striking picture is produced in the ovary. The final maturity and ovulation of a selected group of follicles or a single follicle involves the destruction of all remaining follicles. In the dog and cat this extensive production and sweeping destruction of follicles is an impressive phenomenon. The destruction seems complete, and immediately following ovulation the next succeeding ovogenetic wave begins. We have called this rhythm the 'follicular cycle.'

"In the rat, guinea pig, and dog the follicular cycle coincides normally with the oestrous cycle. In the cat the two cycles may or may not coincide. In man the follicular cycle has no necessary relation to the menstrual cycle, ovulation taking place at any time during the latter cycle." "The ova arise by proliferations from the germinal epithelium in the form of invaginations or cords, forming groups of epithelial cells which are cut off from the epithelium and pass through the tunica albuginea. From one to many cells in each group enlarge and develop into sex cells, the remaining epithelial cells in the group forming the follicle cells." . . . . "Extensive degeneration of the sex cells is a normal process in each cycle." . . . . "Degeneration usually begins in the granulosa cells but occasionally the first indications may be found in the ovum." . . . "New sex cells are formed at all periods of the cycle but the number of these increased gradually, beginning with early metoestrum, to the end of the cycle." . . . . In the mammalia "all the ova of adult life are new formations and are being constantly produced and as constantly destroyed. These processes are part of the rhythmic production and destruction of tissue in the generative tract which is without parallel in any other organ in the body."

STRUCTURE OF THE VERTEBRATES.

By Malcolm E. Little. Ray Long and Richard R. Smith, New York. $3.00. 5⅜ x 8¼; xiv + 392; 1932.

This concise, well-organized text is designed for use in a half-year course in comparative anatomy. The material is presented in three parts. Part I, Vertebrate Zoology, considers the systematic relationships of the groups of vertebrates, one chapter being devoted to each vertebrate class. In the final section of each chapter the embryology of the class is briefly described. Part II, Comparative Morphology, is a study of the comparative structure and development of the different vertebrate organ systems. A chapter on the mechanics of development is included. Part III, Evolution of the Vertebrates, takes up palaeontological evidence omitted in the previous parts, and includes chapters on geographical distribution and adaptive radiations of the vertebrates. Appendix I contains a list of books for reference. Appendix II gives a detailed outline of vertebrate classification. Appendix III consists of a full glossary of the scientific terms employed in the text. The presentation of the subject matter in this book, with emphasis on essentials rather than details, and the clear simple drawings, should especially appeal to the student.

TRAITÉ D'ANATOMIE HUMAINE. *Tome Premier.*

By P. Poirier and A. Charpy. Nouvelle Édition Entièrement Refondue sous la direction de A. Nicolas avec la collaboration de MM. O. Amoédo, Argaud, M. Augier, A. Branca, R. Collin, B. Cunéo, G. Delamare, Paul Delbet, Dieulafé, A. Druault, P. Fredet, Glantenay, A. Gosset, M. Guibé, A. Hovelacque, P. Jacques, Th. Jonnesco, E. Laguesse, L. Manouvrier, P. Nobécourt, O. Pasteur, R. Picou, A. Prenant, R. Rieffel, Rouvière, Ch. Simon, A. Soulié, H. Vallois, J. Verne, B. de Vriese, Weber. Masson et Cie, Paris. 130 francs. 6¾ x 10⅜; 667; 1931 (paper).

The first fascicle of this encyclopedic treatise on anatomy is completely revised in this fourth edition. It includes an Introduction, by L. Manouvrier, and sections on General anatomy and Development of the bones, by J. Verne, and General constitution of the skeleton, by M. Augier. The greater part of the volume, however, is devoted to Augier's treatment of the cephalic skeleton. A bibliography of 23 pages and an index add to the usefulness of the work.

ANATOMIE DES LYMPHATIQUES DE L'HOMME.

By H. Rouvière. Masson et Cie, Paris. 150 francs. 7¼ x 10¾; viii + 489; 1932.

A summary of what is known concerning the lymphatic system in man with the addition of a synthesis of the results obtained

from seven years of research in the author's laboratory. With the exception of the nervous system the author has studied all lymphatics connected with the different organs, for the purpose either of checking results already acquired, or to improve upon incomplete descriptions, or to describe lymphatics up to the present time unknown. All the experiments for each organ were conducted on several individuals in order to gain conception of the norm. Extreme individual variations are not neglected, however, and are dealt with separately. The book is conservatively written and well illustrated.

PHYSIOLOGY AND PATHOLOGY

REFLEX ACTIVITY OF THE SPINAL CORD. *By R. S. Creed, D. Denny-Brown, J. C. Eccles, E. G. T. Liddell and C. S. Sherrington. Oxford University Press, New York.* $3.25. 5½ x 8½; viii + 183; 1932.

This book, which is a further important contribution to the work of the authors on the integrative action of the nervous system, gives an account of mammalian spinal reflexes and their functional mechanism. The anatomical range of the book is limited to the spinal cord, and the point of view is essentially physiological. Following a description of the reflex arc in Chapter I, and of the anatomical structure of the spinal grey matter (afferent root fibers, nerve cell, synapse and ventral horn motoneurones) in Chapter II, various reflexes which are manifested in the skeletal musculature are considered in detail with reference to experimental work. Flexor reflexes of one muscle (tibialis anticus, semitendinosus, or tensor fasciae femoris) are first considered. The phenomenon of latency of response following stimulation, in an animal in which the lower part of the cord has been isolated by transection at the lower thoracic level, is described. Reflex tetanus is discussed and compared with motor tetanus. The Principle of Convergence (i.e., that central terminations of different afferent nerves converge onto the same motoneurone) is illustrated by the observation that the sum of tensions of reflex responses of a muscle elicited from individual afferent nerves far exceeds the maximum motor tension from the stimulation of a motor nerve. Flexor reflexes not confined to a single muscle, but to all flexor muscles of all joints are then considered. The thresholds of reflex response are found to be the same for all muscles.

"The reflex field is a functional entity including extensor as well as flexor muscles, unrestricted by anatomical boundaries such as the limits of the motoneurone centre of any particular muscle, although, owing to the greater involvement of some centres, each nerve has its own characteristic field. The term flexor reflex, therefore, denotes a group of reflexes which employ similar muscles, but in the detailed distribution of motor units differ one from another." Among other further phenomena discussed are summation, afterdischarge, and the nature of the central excitatory state. Apropos the last it is stated that ". . . . *c. e. s.* is probably a depolarization of those parts of the surface membranes of motoneurones on which excitatory impulses impinge, i.e., the synaptic membranes."

In Chapter IV the stretch reflex (resistance from a muscle in full connection with the nervous system) is studied. A special feature of the stretch reflex is that impulses from tension receptors within the muscle itself cause its development (proprioceptive reflex). Phenomena discussed are the tension curve of the stretch reflex; the tendon jerk; action currents of stretch reflex; lengthening and shortening reactions; postural muscle; red and white muscle; rebound and clonus; and the effect of the sympathetic nervous system.

In Chapter V, reflexes in extensor muscles other than postural reflexes are considered, namely, the reflex of crossed extension, and reflexes of ipselateral extension.

In Chapter VI, experimental evidence on central inhibition is presented, and the results summarized. Chapter VII is concerned with lower reflex coördination, mention being made of types of reflex result derivable from direct electrical stimulation of bared efferent nerve, which are likely to be false guides if accepted as instances of normal reflex coördination. A bibliography of 209 references is appended.

HUMORAL AGENTS IN NERVOUS ACTIVITY. *With Special Reference to Chromatophores. By G. H. Parker. The Macmillan Co., New York.* $1.75. 5½ x 8½; x + 79; 1932.

This book contains the substance of a lecture delivered by the author to the members of the Zoological Laboratory of the University of Cambridge. In the first chapter, following a discussion of the receptors, adjustors and effectors of the nervous system of various animal forms, the purpose of the book is stated to be

> to consider the mutual relations of these several constituents of the nervous system both in their fully developed condition and in their evolution, and to discuss in particular the importance of secretion as a controlling factor in the various operations, especially those shown by chromatophores.

Chapter II presents what has been learned through observation and experimentation concerning chromatophores in the vertebrates. The chromatophoral system in fishes and reptiles is essentially nerve-controlled, while in amphibians it is essentially humoral. Chapter III deals with chromatophoral phenomena in crustaceans. From the evidence presented in this and the preceding chapter it appears that

> secretions in the nature of hormones play a considerable part in the control of chromatophores and that these secretions are chiefly of nervous origin. Some of them, like adrenalin and pituitrin, come from well-defined nervous organs . . . . but others appear to come from the nerve terminals of sympathetic fibres, a state of affairs that suggests that the secretory activity of nerves may be a phenomenon of wide application and of great biological significance.

The fourth and final chapter discusses the neuro-humoral hypothesis with respect to effectors, receptors and adjustors. The general conclusion is that the relation of this hypothesis to the nervous system is a problem for future investigation, and that the field appears promising in view of the little that is already known.

THE PHYSIOLOGY OF LARGE REPTILES. *With Special Reference to the Heat Production of Snakes, Tortoises, Lizards and Alligators. Carnegie Institution of Washington Publication No. 425.*

By Francis G. Benedict. Carnegie Institution of Washington, D. C. $4.00 (paper); $5.00 (cloth). 7 x 10; x + 539; 1932.

Dr. Benedict chose the larger land forms of cold-blooded animals for this study in order to be able to make a closer comparison with humans. Furthermore the same experimental methods used in the study of heat production, heat loss and water loss, character of katabolism, reaction to temperature, etc. in man or other warm-blooded animals could be more satisfactorily used on these forms. The work was done in the New York Zoological Park where there is an extraordinarily fine collection of large cold-blooded animals kept under as nearly normal conditions as is possible. The first part of the book is devoted to a detailed description of technique. Then follows (1) a lengthy section on the physiology of large snakes where the boas, pythons and rattlesnakes figure largely in the experiments; (2) short sections on the gaseous metabolism and energy transformation of large alligators and lizards, and (3) a long section on the physiology of large tortoises.

The latter part of the book is taken up with general consideration of metabolism of large cold-blooded animals of different species and a comparison of the cold-blooded and warm-blooded animals. Dr. Benedict finds that all experimental evidence points to the fact that

> the metabolism both per kilogram of body weight and especially per square meter of body surface is much lower with cold-blooded than with warm-blooded animals at the same cell temperature, whether the cell temperature of the warm-blooded animal is lowered by curare, pithing, or hibernation to 16° or 10° for comparison with the cold-blooded animal or whether the cell temperature of the cold-blooded animal is brought to 37°, the normal body temperature of the warm-blooded animal.

In the final section there is a discussion of possible factors explaining differences between metabolism of cold-blooded and warm-blooded forms. Throughout the text will be found many tables, figures and diagrams. There are author and subject indexes.

NEOPLASMS OF DOMESTICATED ANIMALS. *By William H. Feldman. W. B. Saunders Co., Philadelphia.* $6.00 net. 6 x 9¼; 410; 1932.

Because of the relatively rare occurrence of neoplasms in domesticated animals the veterinarians have devoted little attention to their study. This book is the first

English treatise dealing entirely with tumors of domesticated mammals and fowls, and should be a great boon to the veterinary colleges. The first three chapters deal with the general biology and characteristics of neoplasms and with the incidence of neoplasms. The remaining chapters are concerned with a description and classification of various types of neoplasms. Two final chapters are devoted to Experimentally transmissible tumors and Preservation of pathologic material. The book is profusely and well illustrated, and will be useful for reference in all biological laboratories.

THE SIGN OF BABINSKI. *A Study of the Evolution of Cortical Dominance in Primates.*

By John F. Fulton and Allen D. Keller. Charles C Thomas, Springfield, Ill. $5.00. $6\frac{3}{8}$ x $9\frac{7}{8}$; xi + 165; 1932.

Comparatively little study has been devoted to the cortical activity among the lower primates, and consequently this book is to be welcomed not only for the light it throws on animal behavior but also in its bearing on physical anthropology. The authors made a thorough and comprehensive study of the plantar reflex in the monkey, baboon, gibbon and chimpanzee. The experimental method in general was to excise the foot area of the motor cortex in each animal, and then to observe the reflex phenomena exhibited by the animal. Considerable variation was found in each case. The authors discuss also the Babinski phenomenon in man which follows upon injury and destruction of the higher centers of the nervous system. Of considerable usefulness is the section dealing with the technical problems involved in operative and postoperative care of the animals. The book is beautifully produced.

DIE METHODIK DER LOKALISIERTEN REIZUNG UND AUSSCHALTUNG SUBKORTIKALER HIRNABSCHNITTE.

By W. R. Hess. Georg Thieme, Leipzig. 24 marks. $8\frac{1}{4}$ x $11\frac{3}{4}$; 122; 1932 (paper).

The chief value of this contribution is the elaborate descriptions of experimental operative technique on the brain of the cat. There are numerous plates showing points where stimulation was performed, with a catalogue of the attending bodily symptoms. The problem was to find out more about the regulating mechanism of the respiratory and circulatory systems, but the present book deals solely with the experimental technique.

HUIT CONFÉRENCES DE CANCÉROLOGIE. *Centre Anti-Cancéreux de Toulouse, Conférences du Dimanche, sous la direction du Professeur Ducuing. 1re Série.*

By Antoine Béclère, A. Chalier, J. Magrou, de Nabias, Simone Laborde, Louis Delherm, A. Lacassagne, J. Leclercq. Masson et Cie, Paris. 25 francs. $6\frac{1}{2}$ x 10; 229; 1931 (paper).

A symposium of eight lectures on cancer delivered at the *Centre Anti-Cancéreux* at Toulouse, as a Sunday series, under the direction of Professor Ducuing, by eight eminent French specialists. The lectures were on the following subjects: Radiotherapy of fibromas of the uterus; Treatment of cancer of the rectum; Cancer of plants; The rôle of histological examination in guiding the therapeutics of cancer by radium; Radiosensibility of the tissues and its relation to the treatment of cancers; Radiological aspect of tumors of the lungs and mediastinum; Indications for radiotherapy of sarcoma; Traumatism and cancer.

A TEXT-BOOK OF HUMAN PHYSIOLOGY FOR COLLEGE STUDENTS.

By August Krogh. Revised and Edited by Katherine R. Drinker. Lea and Febiger, Philadelphia. $2.75 net. $5\frac{1}{4}$ x $7\frac{3}{4}$; 233; 1932.

The original Danish edition of this book (1908) was designed for students in preparatory schools. In the English edition the authors have revised and rearranged the material in suitable form for an elementary college course. Each subject is dealt with concisely but adequately. There is no attempt to overcrowd the book with unnecessary material or with refer-

ence lists, but it is freely illustrated. A group of 83 laboratory experiments is included and the book is indexed.

TRAITÉ DE PHYSIOLOGIE NORMALE ET PATHOLOGIQUE. *Tome VI: Circulation.*

By J. Demoor, Ph. Fabre, H. Frédéricq, H. Hermann, P. Mathieu, H. de Waele. Published under the direction of G. -H. Roger and Léon Binet. Masson et Cie, Paris. 110 francs. $6\frac{5}{8}$ x $9\frac{5}{8}$; 589; 1932.

This is the sixth volume of a comprehensive series on human physiology, other volumes of which have already been noticed in these columns. Different sections of this volume are written by authorities in their respective fields. Most of the space is devoted to straight physiology of the circulatory system and in this respect it ought to be a useful textbook. There is little new pathological material, however.

DAS CHLOROPHYLL ALS PHARMAKON.

By Emil Bürgi. Georg Thieme, Leipzig. 6.40 marks. $6\frac{1}{2}$ x $9\frac{3}{4}$; 84; 1932 (paper).

A presentation of the results of twenty years work, done in the laboratory of the author on extracted chlorophyll as a tonic and therapeutic agent, and its effect on individual organs and systems of the body. The tonic properties are placed in the foreground, especially in chronic heart diseases. There is a bibliography, but no index.

BIOCHEMISTRY

ANNUAL REVIEW OF BIOCHEMISTRY.

Edited by James M. Luck. Stanford University Press, Stanford University, Calif. $5.00. 6 x $8\frac{3}{4}$; vii + 724; 1932.

This review consists of thirty critical surveys by European and American authorities in their fields, of the current literature in some of the major fields of biochemistry. Each review is comprehensive, but the most significant contributions to the given subject are especially emphasized. The volume should prove invaluable to the specialist in a restricted field, in enabling him to keep abreast of the main developments in fields related to, but distinct from his own.

THE CHEMISTRY OF THE MONOSACCHARIDES AND OF THE POLYSACCHARIDES.

By Hans Pringsheim. McGraw-Hill Book Co., New York. $4.00. $5\frac{3}{4}$ x 9; vi + 413; 1932.

This series of lectures describes and thoroughly classifies the sugars. The book opens with a discussion of the simpler aspects of sugar chemistry and proceeds to the more technical chemistry of the higher saccharides. In connection with the chapter on cellulose there is an account of the rôle of bacteria in soil formation. All of the important work in the biochemistry of saccharides up to 1929 is thoroughly considered.

ALLGEMEINE CHEMIE DER ENZYME. *Wissenschaftliche Forschungsberichte. Naturwissenschaftliche Reihe, Bd. XXVIII.*

By J. B. S. Haldane and Kurt G. Stern. Theodor Steinkopff, Dresden and Leipzig, 22 marks (paper); 23.50 marks (cloth). 6 x $8\frac{3}{4}$; xii + 367; 1932.

This differs in two respects from the English edition reviewed previously (Vol. VI, p. 246) in that both Haldane and Stern have made numerous additions to the text, especially in the sections on specificity, activators, inhibition, crystallization of enzymes, and the mechanism of dipeptidase action. The bibliography has been increased by 400 citations.

KURZES LEHRBUCH DER PHYSIOLOGISCHEN CHEMIE. *Vierte verbesserte Auflage.*

By Paul Hári. Julius Springer, Berlin. 18 marks (paper); 19.60 marks (cloth). $6\frac{1}{2}$ x $9\frac{1}{2}$; ix + 407; 1932.

This textbook has been revised, extended and brought up-to-date since the last edition, which was reviewed in Vol. III, No. 3, of this journal.

BIOCHEMICAL AND ALLIED RESEARCH IN INDIA IN 1931.

Society of Biological Chemists, Bangalore, India. 5½ x 8½; 1932.

SEX

PROSTITUTION AND ITS REPRESSION IN NEW YORK CITY, 1900–1931.

By Willoughby C. Waterman. Columbia University Press, New York. $3.00. 5¾ x 8¾; 164; 1932.

This is an extremely interesting and useful addition to the literature of human biology. It shows how the people of one of the largest cities in the world, where the evolution of *Homo sapiens* may be assumed to have progressed as far in a statistical sense as it has anywhere, have attempted to deal with the problem of prostitution. The record is a comic one. But it is also a tragic one, or at least probably more people would regard it as tragic than as comic. Dr. Waterman tells clearly and intelligently how the law, the police and the courts, and private agencies, have attacked the problem. Then in a final chapter he sums up the results. Up to a point the treatment is objective and realistic. It is not completely so. As one approaches nearer and nearer to the end of the book moral sentiments and judgments more and more tend to replace simple objective description of actualities. It appears that after a long process of trial and error adjustment the New York law has reached a fairly steady state of equilibrium according to which procedure against "nearly every person involved in prostitution" is taken only on the ground that such a person is a *vagrant*. This is interesting as well as funny. It reflects the genius of the American people. Mr. Capone, it will be recalled, languishes in Atlanta because he failed to pay his income tax. The only person connected with the business of prostitution who is *not* what the New York laws constructively regard as a vagrant is the male customer of the gay ladies. He violates no law. The psychology of all this absurdity is simple, and exactly parallels that underlying the antics of our great and noble people about ethyl alcohol. We want prostitution but we want it to be in some manner illegal. To regulate prostitution, as, for example, nuisances in the scatologic department are regulated, would be to admit its existence, and in so far to recognize its legality. We are too moral a people to do anything like that.

Starting from such a base of legal hypocrisy the police and the courts make heavy weather of the business. They have the most difficult job of steering a middle and very narrow course. If they get too rough about prostitution they get into trouble—but so also they do if they get too easy. Consequently the curve of convictions for prostitution makes an extremely zigzaggy line. About the middle of 1930 the number of convictions per unit of time reached a very high peak (over 350 per month), but by December of the same year it had dropped almost to zero. Those with long memories will recall that in that period the Magistrates Courts in New York City had undergone an investigation about the manner of handling arrests for prostitution (called vagrancy).

The activities of private agencies, particularly the Committee of Fourteen, are sufficiently described in the book. We cannot go into them here. But one of the author's main conclusions is that such organizations are absolutely necessary elements in any program for the repression of prostitution. The book is well documented and has an index.

HISTORY OF PROSTITUTION *Among All the Peoples of the World, from the Most Remote Antiquity to the Present Day. In two volumes.*

By Paul Lacroix. Translated from the French, with an Introduction by Samuel Putnam. Covici, Friede, New York. $12.50. 6 x 9; xv + 1481; 1931.

The original French edition appeared in 1854. While the author collected an amazing amount of material bearing on prostitution from the early Chaldaean times down to the reign of Henri IV, he confined himself largely to ancient Greece and Rome and France from the Roman era. For this reason the history falls short of being a complete survey. Its usefulness is chiefly as a source book wherein will be

found much otherwise inaccessible material concerning the types of prostitution in the various epochs; laws which have been enacted to control its spread; the place of prostitution in religious rites; famous courtesans and their influence in politics and in the arts; venereal diseases and methods of treatment in vogue in the different eras; and the effect on prostitution of the spread of Christianity. The detailed index will be found useful. Samuel Putnam includes an introduction to the translation.

HUMAN STERILIZATION. *The History of the Sexual Sterilization Movement.*

By J. H. Landman. The Macmillan Co., New York. $4.00. 5½ x 8½; xviii + 341; 1932.

This excellent book is written by a man thoroughly trained in jurisprudence and exhibits a refreshing sanity, clarity of reasoning and realistic freedom from moral sentiments and judgments. All the sterilization laws enacted by the various states of this country are thoroughly reviewed and analyzed. Of such laws there are 42 currently valid on the statute books of 27 states. Of these four are voluntary, 24 are compulsory, six are both voluntary and compulsory, and four require the consent of the patient's representatives. Thirty states have at one time or another enacted such legislation.

The book will be invaluable as a reference source. It has a bibliography covering 17 pages and an adequate index.

WILL IT BE A BOY? *Sex-Determination According to Superstition and to Science.*

By F. Økland. The Century Co., New York. $1.50. 5 x 7½; x + 116; 1932.

Following a description of various superstitions which have prevailed in the past regarding the factors which influence sex-determination in the unborn child, the author surveys, in simple, non-technical language, present-day scientific knowledge of the basic mechanisms involved. Besides a presentation of the chromosome theory, various phenomena concerning which the layman usually has either vague or erroneous ideas, such as parthenogenesis, sex-reversal, gynandromorphism, and the significance of sex-ratio, are discussed. Although references are made to experimental work with, and facts peculiar to, lower forms, emphasis is concentrated primarily on material applying to human beings.

BIOMETRY

MATHEMATICAL PSYCHICS. *An Essay on the Application of Mathematics to the Moral Sciences. No. 10 in Series of Reprints of Scarce Tracts in Economic and Political Science.*

By F. Y. Edgeworth. London School of Economics and Political Science, London. 5 shillings. 5⅜ x 8½; viii + 150; 1932 (paper).

In this essay Edgeworth applied mathematical methods, not only to strictly economic problems, as Cournot had done, but to ethical and political questions as well. Finding that when the number of competitors is limited competition does not lead to a determinate contract, he felt the need of some principle of arbitration. This he found in the Utilitarian principle of the greatest possible sum-total of pleasure, a principle which does not necessarily imply equality, since persons differ in capacity for happiness. Among the correlaries which he deduced from this principle are the limitation of population and the choice of the more capable for parenthood. Thus Malthusianism and eugenics received their mathematical justification.

PSYCHOLOGY AND BEHAVIOR

PURPOSIVE BEHAVIOR IN ANIMALS AND MEN.

By Edward C. Tolman. The Century Co., New York. $5.00. 5¾ x 9; xiv + 463; 1932.

In this book the author presents a new system of psychology which he calls purposive behaviorism.

It conceives mental processes as functional variables intervening between stimuli, initiating physiological states, and the general heredity and past training of the organism, on the one hand, and final resulting

responses, on the other. These intervening variables it defines as behavior-determinants. And these behavior-determinants it subdivides further into (1) immanent purposive and cognitive determinants, (2) capacities and (3) behavior adjustments. All three of these types of determinant are to be discovered, in the last analysis, by behavior experiments. They have to be inferred "back" from behavior. . . . . There is nothing private or mentalistic about them.

Part I discusses the author's conception of behaviorism, which is, in brief, that "behavior presents characterizable and defining properties of its own, which are other than the properties of the underlying physics and physiology." He terms this molar behavior in contradistinction to Watson's molecular behavior. Parts II and III present a wealth of behavioristic experiments on the rat chiefly, and on the cat, ape and man. The results of these experiments offer the facts from which the new system is formulated. Part IV, in which speech and introspection, sensation and images, and feelings and emotion are considered from the behavioristic viewpoint seemed of especial interest. Part V deals with motivation (appetites, aversions, etc., determining action) and learning. The latter subject is exhaustively treated. The Conditioned Reflex Theory, the Trial and Error Theory and the Gestalt Theory are subjected to close analysis, and the Laws of Learning envisaged by Purposive Behaviorism expounded. In Part VI the variables assumed by the three main varieties of academic psychology—"Individual Psychologies," "Normative Psychologies" and "Complete Psychologies"—are surveyed, and the final variables of Purposive Behaviorism are elucidated. In the final chapter of the book the relation of the present system to other systems is discussed. The chapter concludes with a brief consideration of the philosophical implications of Purposive Behaviorism.

BEHAVIOUR ASPECTS OF CHILD CONDUCT.
By Esther L. Richards. The Macmillan Co., New York. $2.50. 5⅛ x 7¾; xv + 299; 1932.

A series of lectures delivered before the Baltimore branches of the Child Study Association of America form the substance of this book. Dr. Adolf Meyer contributes a foreword. Doctor Richards is well known for her penetrating analysis of behavior problems, particularly in the young, and of her sensible methods of attacking these problems. Invariably it is in the parent or guardian or teacher that she finds the origin of the trouble when dealing with a child who is not handicapped by abnormalities. The book is devoid of technicalities and therefore readily comprehended by the general reader. Parents and teachers would do well to include this in their list of guide books. While one assumes that there are numerous cases that cannot always be solved as readily as most of those given in Dr. Richards' book, still the reader will receive many valuable suggestions in the management of children and will be the more readily able to recognize cases that should be turned over to the specialist. If the reader of this book wishes to do further reading along this line he can go back to the work of twelve volumes written about 2000 years ago by Marcus Fabius Quintilianus, a famous Roman teacher and orator, on the *Training of an Orator*, in which much sound advice will be found on the rearing of the young very much along the lines advocated by specialists of today.

THE CRAVING FOR SUPERIORITY.
By Raymond Dodge and Eugen Kahn. Yale University Press, New Haven. $1.50. 5¼ x 8; viii + 69; 1931.

We have heard so much about these superiority and inferiority complexes that it is good to find those who deal simply with a natural craving, a part of all of us, which is an important factor in the development of personalities, social adjustments, and cultures. This craving has its biological basis in the impulse to live which is a characteristic of all organisms.

The authors distinguish between genuine, matter-of-fact, superiority and the feeling of superiority. The environment-type of personality strives for genuine superiority which will enable him to realize and increase his own and the community's genuine values, whereas the ego-type strives only for prestige, not genuine accomplishment. There seem to us certain

difficulties in this concept of matter-of-fact superiority. A person's military prowess is a matter of fact, but is there anything objective in the system of values of his community which leads it to esteem military prowess above artistic or intellectual ability?

Our feelings of superiority and inferiority are cleverly called to account in the last analysis by the fact that time cannot be conquered, that old age and death are inevitable. But in conquering the fear of death "we may have reached the highest degree of relative superiority over time which is attainable for human beings."

A Short Introduction to the History of Human Stupidity.

By Walter B. Pitkin. Simon and Schuster, New York. $3.50. 7 x 10; xiii + 574; 1932 (paper).

In this short introduction, which nevertheless runs to something over 500 pages, Mr. Pitkin gives us a choice sample of stupidities which range from those affecting only the individual to those which have been empire shattering. He analyzes the elements of stupidity and shows the various pattern arrangements in numerous case histories. The blunders of industrialists, statesmen, educators or soldiers furnish him with countless and frequently entertaining illustrations. He believes "that for every enlightened act in human history there have occurred fully a million deeds injurious to the race because of dull prejudice, a single-track mind, laziness, faulty reasoning, forgetfulness, pride or malice," and that "It is physically impossible for anybody to act intelligently even one-tenth as often as to act stupidly." Stupidity in the human race probably had its inception during the hundreds of thousands of years when our forebears, suffering from cold and half starved, were able to exist only because of their insensitivity to their environment. In other words our existence today is due solely to the dull and slow perceptions of early man. Natural selection weeded out the intelligent. The author points a way to rise above our stupidities, namely: "to analyze them down to the smallest atom and then find methods of control through education, police or chemical."

Since the author does not take himself too seriously this is an amusing book. It has a good index.

Why We Don't Like People.

By Donald A. Laird. Mohawk Press, New York. $2.00. 5¼ x 8; xvii + 166; 1931.

The dedication of this book more or less speaks for the contents. It is "To the seven thousand business men and women who sought guidance and insight through the personal advisory service and whom the author tried to help." In the publication of this volume the attempt is made to extend the help which was given to the above mentioned 7,000 men and women to the world at large. According to the author it is a "brief, practical presentation of what is actually found by experimental methods in studying human qualities, other than intelligence and sensory functions. It deals principally with the responses which these qualities arouse in those about us." Theoretically, at least, those who diligently heed its warnings and advice should be able to acquire those elusive characteristics which seem so highly desirable in human relations. The experimental work was done in the psychological laboratory at Colgate University.

The Reliability of the Maze and Methods of Its Determination. *Comparative Psychology Monographs, Vol. 8, No. 5, Serial No. 40.*

By Kenneth W. Spence. The Johns Hopkins Press, Baltimore. 75 cents. 6¾ x 10; 45; 1932 (paper).

Two aspects of this problem were considered: first, the significance of the various methods of determining the reliability of maze scores; and second, the degree and significance of the reliability of the maze used in the present experiment. The sub-

jects of the experiment were human individuals. Two mazes were used.

They were both high relief finger mazes constructed, as suggested by Miles, of No. 14 copper wire ($\frac{1}{16}$-inch in diameter) bent into long square cornered staples of suitable lengths for the pattern desired and fastened on to a wooden panel. The panel was 18 inches square, 12 inches of which was covered by the pattern. Ordinary rubber feet were fastened at the corners in order to make the panel more satisfactory while in use. Two patterns were used, both being of the multiple T type.

The writer finds that the methods of (1) correlation of the sum of all errors for the first half of the maze with the sum of all the errors for the second half of the maze and (2) correlation between the results of two mazes, to be the most valid. Included in the paper are tables and diagrams showing the results of the tests. A bibliography of 32 titles is given.

PSYCHOPATHIC PERSONALITIES.

By Eugen Kahn. Yale University Press, New Haven. $5.00. 6 x 9; xii + 521; 1931.

This thorough and intensive book, which was first published in German, presents Dr. Kahn's multidimensional structurally analytic approach to the psychopathic personality. The first chapters take up the author's conception of personality structure and consider it in the light of views of leading psychiatrists of the modern German school (Klages, Kehrer, Kronfeld, H. Hoffman, Stern, Kretschmer, Schneider *et al.*). Personality is regarded as consisting of three interrelated strata: impulse, temperament and character. Two definitions of psychopathic personality are presented.

The causal definition: "By psychopathic personality we understand those personalities which are characterized by quantitative peculiarities in the impulse, temperament or character strata. The degree of peculiarities is relative. It is dependent on the totality of the individual personality." The teleological definition: "By psychopathic personalities we understand personalities whose unified goal-striving is impaired by quantitative deviations in the ego- and foreign valuation leading to the establishment of pseudo-values and to the striving toward pseudo-goals.

Psychopathic personalities are then considered specifically from the point of view of impulse, temperament (dysthymic personalities), and character (dystonic personalities). One chapter is devoted to analyzing complex personality types. In the final chapter the dynamic developmental nature of personality is indicated. A bibliography is appended.

PSYCHOLOGICAL RACKETEERS.

By Dorothy H. Yates. Richard G. Badger, Boston. $2.00. 5 x $7\frac{5}{8}$; 232; 1932.

In view of the enthusiasm with which a gullible and uninformed public time after time embraces the Health-Happiness-and-Success-assuring courses offered by that type of "psychological racketeer" variously called "applied psychologist," "mystic psychologist," "astro-psychologist," "menticulturalist," "mental scientist," etc., who travels from city to city, advertising in extravagant terms his powers and qualifications, the author of this book determined to ferret out the true facts of the case and make them available. The result of her investigation is presented in this book in an amusingly written account of the quackery and fraud which she found. The methods of these "psychologists" and their teachings are analyzed, and their lack of personal qualifications exposed. The author considers the basis of their undeniable success and attributes it to their practical knowledge of universal human desires and discontents. These are constant factors which can be skillfully played on with assurance of financial gain. In regard to these racketeers the author states that

even the best of them probably do much more harm than good. Their 'uplift' is too mixed with untruth. Much as human beings need inspiration, it should come from a sound source. Otherwise, delusion and woeful disappointment are the almost inevitable final result. . . . . All "applied psychologists" appear to be appallingly ignorant of the genuine science of psychology.

The final chapter is devoted to a discussion of scientifically sound views on suggestion and autosuggestion, as held by the trained psychologist.

THE PRINCIPLES OF PSYCHOPHYSIOLOGY. *A Survey of Modern Scientific Psychology. Volume III. Cerebration and Action.*

By Leonard T. Troland. D. Van Nostrand Co., New York. $4.00. 5½ x 8½; xxiv + 446; 1932.

This book deals with two groups of problems: cerebration and action. In regard to cerebration the author holds the relationship between behavior and the cerebral cortex to be one of point to point correspondence. He does not hesitate to hypothesize liberally where experimental confirmation of his views is lacking. Under *Action* the laws associating consciousness with factors in the efferent sector of the response arc are discussed. The subjects of instinct, emotion, purpose and motivation are embraced. Here again hypothesis far outruns experiment. The book, although great in scope, is written on a pedantic plane rather than an experimental one, and will be of little practical value as a contribution to the advancement of precise knowledge regarding consciousness and related phenomena.

AN EXPERIMENTAL STUDY OF PITCH RECOGNITION. *Psychological Monographs, Vol. XLII, No. 6, Whole No. 193.*

By Laurence A. Petran. Psychological Review Co., Princeton, N. J. $1.75. 6¾ x 9¾; 124; 1932 (paper).

The phenomenon of absolute pitch has excited much interest among both musicians and psychologists. As a result of carefully controlled experiments the author finds that there is no gifted group of people who have perfect absolute pitch, who can tune a tone variator exactly and invariably to the desired note from memory alone. Some subjects come fairly close to the exact note, while the rest range in a fairly regular gradation from very good to very poor. The method used by most investigators of giving at one sitting a long series of notes which the subject is to name one after the other has little value, since it does not discriminate between absolute and relative pitch.

THE MIND IN ACTION. *A Study of Motives and Values.*

By A. Campbell Garnett. D. Appleton and Co., New York. $2.00. 5 x 7⅞; xiii + 226; 1932.

A subjective analysis of instincts, habits, and motives. Little mention is made of the work of others.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

THE JOY OF IGNORANCE.

By T. Swann Harding. William Godwin, New York. $3.00. 5¾ x 8½; 369; 1932.

Certain enterprizing men have discovered that scientific statements may be used to sell goods. It has not always happened that the statements in question were true but it is not a matter of record that this discourages buyers. On the contrary, the reports of the U. S. Food and Drug Administration and of the American Medical Association indicate that a number of highly lucrative businesses have been built up as a result of misleading claims. Dr. Harding, whose training is that of a biological chemist, has made an interesting collection of opinions of authorities relative to several health fads including the sun-tan cult, trick diets, and the use of alcohol, tobacco, and coffee.

SODOMY'S BEST LIBERATOR. *A Scientific Adaptation.*

By Marcus Rosenberg. Marcus Rosenberg, 440 East 146th St., New York. 75 cents. 4¾ x 7¼; 16; 1932 (paper).

Careful study of this too expensive pamphlet failed to reveal to our dull comprehension just what it is that Mr. Rosenberg thinks is sodomy's best liberator. Reginald, the Office Boy, says he knows, but this only confirms our suspicion that Reginald has been associating with bad boys in the neighborhood.

THE COST OF BIOLOGICAL BOOKS IN 1932

By JOHN R. MINER

Department of Biology, School of Hygiene and Public Health, Johns Hopkins University

FOLLOWING the usual custom of the QUARTERLY REVIEW OF BIOLOGY, the present paper reports on the cost of the books which have been received for review during 1932. The books are classified by origin by the same rubrics as in previous reports. The prices of foreign books are converted into dollars on the basis of the exchange at the time the books were received.

The total number of pages reviewed in 1932 is 144,724, an increase of 19.4 per cent over 1931 and of 75.3 per cent over 1926.

As may be seen from Table 2 the trend of the average prices per page of commercially produced biological books has been downward from 1931 to 1932. Combining all the books reviewed in 1932 the average price per page was 1.043 cents, a decrease of 11.1 per cent as compared with 1931 and of 5.2 per cent as compared with 1926. This is in line with the international decline in general price levels, but biological books do not seem to have kept pace with other goods in their rate of decline. Thus the books published in the United States show a decrease in price of 10.7 per cent from 1926 to 1932, whereas the wholesale price index of the United States Bureau of Labor Statistics declined

TABLE 1

Prices of biological books, 1932

ORIGIN	TOTAL PAGES	TOTAL COST	PRICE PER PAGE
			cents
German	15,959	$254.78	1.60
English-American	10,717	158.25	1.48
British Government	135	1.96	1.45
Other countries	4,355	44.49	1.02
United States	87,793	873.98	1.00
England	11,616	102.89	0.89
France	9,141	54.93	0.60
U. S. Government	5,008	18.05	0.36

TABLE 2

Comparison of the prices of biological books from 1926 to 1932

ORIGIN	AVERAGE PRICE PER PAGE							CHANGE + OR − FROM 1931 TO 1932		CHANGE + OR − FROM 1926 TO 1931	
	1926	1927	1928	1929	1930	1931	1932	Absolute	Relative	Absolute	Relative
	cents	*cents*	*cents*	*cents*	*cents*	*cents*	*cents*	*cents*	*per cent*	*cents*	*per cent*
English-American	1.55	1.39	1.46	1.90	1.91	2.27	1.48	−0.79	−34.8	−0.07	−4.5
Other countries	1.51	0.78	1.13*	1.68	0.97	1.53	1.02	−0.51	−33.3	−0.49	−32.5
England	1.28	1.14	1.09	1.29	1.13	1.19	0.89	−0.30	−25.2	−0.39	−30.5
United States	1.12	1.09	1.14	1.14	1.09	1.05	1.00	−0.05	−4.8	−0.12	−10.7
Germany	1.09	1.20	1.48	1.65	1.82	1.75	1.60	−0.15	−8.6	+0.51	+46.8
British Government	—	0.96	1.26	0.39	1.19	1.03	1.45	+0.42	+40.8	+0.49	+51.0†
France	0.35	0.36	0.45	0.47	0.47	0.69	0.60	−0.09	−13.0	+0.25	+71.4
U. S. Government	0.31	0.24	0.21	0.23	0.30	0.28	0.36	+0.08	+28.6	+0.05	+16.1

* With two special treatises omitted as explained in Vol. III, p. 601.

† Change from 1927 to 1931.

about 35 per cent in the same period. The prices of French and German biological books show sharp increases from 1926 to 1932, although from 1931 to 1932 they decreased. German books are now the most expensive of any of the groups, while the French books, in spite of the general upward trend in their price, are still less expensive than any other group of commercially produced scientific books. The decrease in the prices of English and English-American books reflects the decrease in the value of sterling during the past year. The biological books published by the United States Government are, as usual, at the bottom of the list.

The reader should bear in mind that these reports are based on small samples of books in general and, for some countries, on small samples of the biological books published. He should therefore be cautious in applying conclusions drawn from this material to the general domain of book prices.

INDEX

Abderhalden, E. (Ed.), Handbook of Biological Methods, 101, 111, 121, 122, 246
Abel, O., The Place of Man among the Vertebrates, 346
Abraxas-type species, sex differences in mortality in, 313
Academia Nacional de Ciencias (Argentina), Bulletin, 347
Acanthocephala, cell constancy in, 63
Ackerson, L., Children's Behavior Problems, 374
Acta Forestalia Fennica, 365
Acuna, C., Women for Sale, 232
Adams, G., Psychology: Science or Superstition?, 252
Adolph, E. F., The Regulation of Size as Illustrated in Unicellular Organisms, 226
Aesthetic notions in animal breeding, 84
Alexander, J. (Ed.), Colloid Chemistry, 369
Allee, W. C., Animal Life and Social Growth, 480
Allison, W. H., *et al.*, (Ed.), A Guide to Historical Literature, 231
Ambard, L., Normal and Pathological Physiology of the Kidneys, 243
Amitotic division of nuclei, 64
Aquatic animals, utilization of water colloids by, 210
Aristotle, 377
Armstrong, E. F., and Armstrong, K. F., The Glycosides, 370
Ashbrook, F. G., The Blue Book of Birds of America, 115
The Green Book of Birds of America, 115
The Red Book of Birds of America, 115
Auditory capacity, 444
Ayres, C., Huxley, 351

Bacteria, influence of temperature on, 172
von Baer's divergence theory, 93
Bainbridge, F. A., The Physiology of Muscular Exercise, 244
Baitsell, G. A., Manual of Animal Biology, 482
Baker, H. G., The New Road to Civilization, 233
Baker, O. E., A Graphic Summary of American Agriculture, etc., 357
Baldwin, S. P., *et al.*, Measurements of Birds, 250
Ball, O. M., A Contribution to the Paleobotany of the Eocene of Texas, 116
Barbour, T., A Peculiar Roosting Habit of Bats, 307–312
Bardier, E., *et al.*, Normal and Pathological Physiology, 366
Barrett, M. F., Field Key to the Genera of the Wild and Cultivated Hardy Trees of the Northeastern United States and Canada, 117
Barrett, R. and K., A Yankee in Patagonia, Edward Chace, 353
Barrows, H. R., Biological Types and Principles, 105
Basler, A., The Center of Mass of Living Men, 365
Bats, roosting habit of, 307
Battley, H., Single Finger Prints, 356
Baur, E., Fischer, E., and Lenz, F., Human Heredity, 223
Bayne-Jones, S., Man and Microbes, 364
Becker, Elery R., The Present Status of Problems Relating to the Ciliates of Ruminants and Equidae, 282–297
Béclère, A., *et al.*, Lectures on Cancer, 490
Beeton and Pearson's study of inheritance of longevity, 80
Bell, E. T., The Queen of the Sciences, 373
Bell's study of inheritance of longevity, 77
Benedict, F. G., The Physiology of Large Reptiles, 489
Bennett, W. C., Archaeology of Kauai, 355
Benson, S. B., Three New Rodents from Lava Beds of Southern New Mexico, 484
Bermuda, fauna of, 411
Berry, R. J. A., and Gordon, R. G., The Mental Defective, 251
Betz, Barbara J., The Population of a Nest of the Hornet *Vespa maculata*, 197–209
Bigelow, H. B., Oceanography, 103
Binet-Sanglé, The Ancestors of Man, 346
Biochemical and Allied Research in India, 122, 491
Biochemistry (book reviews), 120, 246, 369, 491
Der Biologe, 104
Biological peculiarities of oceanic islands, 405
Biometry (book reviews), 123, 249, 372, 493
Birds, sex differential mortality in, 314
Birnbaum, K., Criminal Psychopathology and Psychobiological Criminology, 111
Bjerre, P., The Remaking of Marriage, 123
Body size and cell constancy, 59
Boldrini, M., The Fertility of Biotypes, 105
Bonar, J., Theories of Population from Raleigh to Arthur Young, 107
Bonne-Wepster, J., and Brug, S. L., The Subgenus Stegomyia in Netherland India, 483
Books, biological, cost of, 498

Borradaile, L. A., and Potts, F. A., The Invertebrata, 483
Botany (book reviews), 116, 240, 363, 484
Bowen, E., An Hypothesis of Population Growth, 110
Brandt, W., Foundations of Constitutional Anatomy, 366
Branom, F. K. (Ed.), New Census Atlas of the World, 233
Brash, J. C., The Aetiology of Irregularity and Malocclusion of the Teeth, 117
Breeding, aesthetic notions in, 84
Briffault, R., The Mothers, 112
Britten, J., and Boulger, G. S., A Biographical Index of Deceased British and Irish Botanists, 357
Brues, C. T., and Melander, A. L., Classification of Insects, 359
Brumley, O. V., A Text-book of the Diseases of the Small Domestic Animals, 240
Bryk, F., Circumcision in Man and Woman, 248
Bucke, R. M., Cosmic Consciousness, 124
Budd, W., Typhoid Fever, 119
Buick, T. L., The Mystery of the Moa, 358
Buller, A. H. R., Researches on Fungi, 116
Bürgi, E., Chlorophyll as a Drug, 491
Burke, J. B., The Emergence of Life, 347
Burlingame, L. L., *et al.*, General Biology Laboratory Manual, 349
Burt, C. E., Teiid Lizards of the Genus Cnemidophorus, 113

Cahen, A., Statistical Analysis of American Divorce, 482
Cain, J. R., Principles and Practice of Hygiene, 120
Cajander, A. K., The Organization of Forest Research in Finland, 365
Calderwood, W. L., Salmon Hatching and Salmon Migrations, 240
Calverton, V. F. (Ed.), The Making of Man, 110
Camp, B. H., The Mathematical Part of Elementary Statistics, 124
Campbell, A. M., The Black Death and Men of Learning, 235
Cancer, hereditary factor in, 255
Cannon, W. B., The Wisdom of the Body, 368
Carter, H. R., Yellow Fever, 244
Castle, W. E., and Sawin, P. B., Contributions to the Genetics of the Domestic Rabbit, 476
Caullery, M., The Problem of Evolution, 101
Causey, D., Uninvited Guests, 362
Cell constancy and body size, 59
lineage, 59
Chamberlin, J. C., The Arachnid Order Chelonethida, 116, 237
Chapman, F. M., Handbook of Birds of Eastern North America, 482
Chapman, R. N., Animal Ecology, 239
Chatterjee, N. C., *et al.*, Investigations on the Spike-Disease of Sandal, 117
Cheslock, L., Introductory Study on Violin Vibrato, 245
Chevallier, P., and Bernard, J., Hodgkin's Disease, 369
Chidester, F. E., Zoölogy, 360
Chinnery, E. W. P., Territory of New Guinea, Anthropological Reports, 111
Chittenden, R. H., The Development of Physiological Chemistry in the United States, 120
Chorion as criterion of identical twins, 298
Christ, G. E., and Haydon, A. L. (Ed.), The Nuttall Encyclopædia, 252
Ciliates of ruminants and Equidae, 282
Clark, A., The Cool-Water Timms Point Pleistocene Horizon, 346
Clark, A. H., A Monograph of the Existing Crinoids, 114
Nature Narratives, 227
Clements, F. E., and Shear, C. L., The Genera of Fungi, 241
Codling moth, sex differential mortality in, 318
Cohn, A. E., Medicine, Science and Art, 111
Collins, S. D., The Health of the School Child, 245
Columbia University, a Quarter Century of Learning, 1904–1929, 125
Connell, F. H., *Gigantomonas Lighti* Sp. Nov., a Trichomonad Flagellate from *Kalotermes* (*Paranotermes*) *simplicicornis* Banks, 363
Consciousness, 402
Corset, J., Coaptation in the Insects, 104
Cost of biological books, 498
Cotton, E. H. (Ed.), Has Science Discovered God? A Symposium of Modern Scientific Opinion, 340
Coulter, J. M., *et al.*, Textbook of Botany, 117
Craciun, E. C., Tissue Culture in Experimental Biology, 104
Crawford, Meredith P., and Brundage, Everett G., Recent Methods of Generating Sound Stimuli for Use in Testing the Auditory Capacity in Animals, 444–457
Crawley, E., Dress, Drinks, and Drums, 371
Creed, R. S., *et al.*, Reflex Activity of the Spinal Cord, 488
Crocker, W. R., The Japanese Population Problem, 232
Crookshank, F. G., The Mongol in Our Midst, 482
Crosby, P., A Cartoonist's Philosophy, 253
Cuny, L., and Quivy, D., Present Knowledge of the Testicular Hormone, 371

Darwin, C., A Naturalist's Voyage round the World in H.M.S. "Beagle," 103
Dautrebande, L., Physiopathology of the Thyroid, 118
Davis, E. C., Ancient Americans, 232
Davison, A., Mammalian Anatomy, 118
Death rate of bacteria, 181
deFord, M. A., Love-Children, 233
Delafosse, M., The Negroes of Africa, 230
Demoor, J., *et al.*, Normal and Pathological Physiology, 491
Dennis, E. W., The Life-Cycle of *Babesia bigemina*, 363
Density of population and microclimate, 28
De Omnibus Rebus et Quibusdem Aliis (book reviews), 125, 252, 376, 497
Deuel, J. V., Indians, Crocodiles and Monkeys, 253
Developmental risks, 47
Dewar, D., Difficulties of the Evolution Theory, 222
Dhar, N. R., Senescence, an Inherent Property of Animal Cells, 68–76
Dickinson, R. L., and Beam, L., A Thousand Marriages, 248
Bryant, L. S., Control of Conception, 371
Ditmars, R. L., Snakes of the World, 236
Strange Animals I Have Known, 240
Doane, R. W., Common Pests, 238
Dodge, R., and Kahn, E., The Craving for Superiority, 494
Dorsal mid-line, 47
Dorsey, G. A., Man's Own Show: Civilization, 221
Dover, C., *et al.*, Investigations on the Spike-disease of Sandal, 365
Driesch, Hans, 378
Duggan-Cronin, A. M., The Bantu Tribes of South Africa, 112
Dunlap, J. W., and Kurtz, A. K., Handbook of Statistical Nomographs, Tables and Formulas, 373
Duration of life, inheritance of, 77
Dusseau, A., Contribution to the Ecological Study of Wheat, 486
Dysgenic effects of aesthetic selection, 85

Easter Island, biota of, 405
Eaton, A., A Bibliography of Social Surveys, 234
Eckstein, G., Lives, 483
Noguchi, 110
Ecology of populations, 27
Edgeworth, F. Y., Mathematical Psychics, 493
Edwards, Thomas I., Temperature Relations of Seed Germination, 428–443
Eisler, R., The Messiah Jesus and John the Baptist, 349
Ellis, D., Sulphur Bacteria, 363
Embree, E. R., Brown America, 230
Entelecheia, 377
Epigenesis, 388
Esdaile, P. C., Economic Biology for Students of Social Science, 104
Etiology in pathology, 128, 130
Eubank, E. E., The Concepts of Sociology, 482
Eutely and body size, 59
Evans, H. McL., and Swezy, O., Ovogenesis and the Normal Follicular Cycle in Adult Mammalia, 486
Evaporation and density of population, 31
Evolution (book reviews), 100, 218, 345, 474
Evolution of standards, 87
Excretory system as method of classification of trematodes, 458
Eyster, W. H., College Botany, 485

Faust, Ernest Carroll, The Excretory System as a Method of Classification of Digenetic Trematodes, 458–468
Fearnow, E. C., Goldfish: Their Care in Small Aquaria and Ponds, 116
Federighi, H., Studies on the Oyster Drill, 116
Feldman, W. H., Neoplasms of Domesticated Animals, 489
Field, J. A., Essays on Population and Other Papers, 109
Fischel, A., Outline of the Evolution of Man, 243
Fishes, sensitivity to sound, 326
water regulation in, 1
Ford, E. B., Mendelism and Evolution, 224
Fortune, R. F., Sorcerers of Dobu, 352
Fortuyn, A. B. Drooglever, Modern Research on Human Twins, 298–306
Foster, G. S., and Kranz, L. G., Health, 368
Foucher, R., The Problem of Life, 226
Fox, C., The Mind and Its Body, 373
France, Ministry of War, The Work of the Military Health Service in Algeria, 235
Franz, V., Viviparus, 362
Frost, H. W., Miraculous Healing, 229
Fulton, J. F., and Keller, A. D., The Sign of Babinski, 490

Gage, S. H., The Microscope, 348
Galán F., Studies on the Spermatogenesis of the Beetle *Phytodecta variabilis*, 478
Galapagos Islands, fauna of, 416
Gallaudet, B. B., A Description of the Planes of Fascia of the Human Body, 243
Gardiner, J. S., Coral Reefs and Atolls, 238
Gardner, A. D., Microbes and Ultramicrobes, 241
Gardner, G., Researches on Spirochetotics in the Montreal District, 120

Garnett, A. C., The Mind in Action, 497
Gause, G. F., Ecology of Populations, 27–46
Gene theory, 395
and recapitulation theory, 96
General Biology (book reviews), 102, 224, 347, 478
Genetics, (book reviews), 101, 223, 346, 476
Genetics and pathology, 127
Georg, E., The Adventure of Mankind, 221
Germinal stability and variability, 48
Germination, temperature relations of, 428
Germplasm theory, 393
Gibbs, W., Bird Life at the Pole, 115
Gillespie, L. J., Physical Chemistry, 370
Ginsburg, I., Juvenile and Sex Characters of *Evorthodus lyricus*, 116
Glaister, J., A Study of Hairs and Wools, 366
Goebel, K., Formation of Flowers and Shoots, 240
Goiffon, R., Manual of Clinical Coprology, 367
Gowanloch, J. N., and Dauenhauer, J. B., Jr., Sea Fishes and Sea Fishing in Louisiana, 362
Grant, U. S., IV, and Gale, H. R., Catalogue of the Marine Pliocene and Pleistocene Mollusca of California and Adjacent Regions, 345
Graves, W. P., Female Sex Hormonology, 372
Gray, H., and Ayres, J. G., Growth in Private School Children, 354
Gray, J., Experimental Cytology, 103
Gray, W. F., Five Score, 355
Greaves, J. E., and Greaves, E. O., Elementary Bacteriology, 365
Green, M. M., An Unrecognized Shrew from New Jersey, 484
Greenman, M. J., and Duhring, F. L., Breeding and Care of the Albino Rat for Research Purposes, 240
Greenwood, A. W. (Ed.), Proceedings of the Second International Congress for Sex Research, 249
Gregory, J. C., A Short History of Atomism, 253
Gregory, J. W., Race as a Political Factor, 233
Grimpe, G., and Wagler, E. (Ed.), Fauna of the North and Baltic Seas, 115, 483
Grinnell, J., A New Pocket Gopher from Southeastern California, 116
A Relic Shrew from Central California, 484
Type Localities of Birds Described from California, 363
Guchteneere, R. de, Judgment on Birth Control, 247
Guenther, K., A Naturalist in Brazil, 227
Gulick, Addison, Biological Peculiarities of Oceanic Islands, 405–427
Gurwitsch, A., and Gurwitsch, L., Mitogenetic Rays, 349
Guyer, M. F., Animal Biology, 361

Habitat of early vertebrates, 1
Haeckel's recapitulation theory, 93
Haldane, J. B. S., and Stern, K. G., General Chemistry of the Enzymes, 491
Haldane, J. S., The Philosophical Basis of Biology, 224
Halverson, H. M., An Experimental Study of Prehension in Infants by Means of Systematic Cinema Records, 375
Hammond, J., Growth and the Development of Mutton Qualities in the Sheep, 479
Hampil, Bettylee, The Influence of Temperature on the Life Processes and Death of Bacteria, 172–196
Hance, R. T., The Machines We Are, 348
Hannan, A. M., The Influence of Weather on Crops, 486
Harding, T. S., The Degradation of Science, 252
The Joy of Ignorance, 497
Hári, P., Physiological Chemistry, 491
Harvey, B. C. H., Simple Lessons in Human Anatomy, 242
Haurowitz, F., Progress of Biochemistry, 370
Hawaiian Islands, biota of, 418
Head, vulnerability of, 56
Health Organization, League of Nations, Quarterly Bulletin, 482
Healthy and pathic, 133
Heat resistance of bacteria, 185
Hedges, E. S., Colloids, 370
Henderson, G. C., Fiji and the Fijians, 1835–1856, 351
Henry, D. P., Coccidiosis of the Guinea Pig, 484
The Oocyst Wall in the Genus Eimeria, 484
Hereditary factor in human neoplasms, 255
Heredity and *entelecheia*, 390
Herrick, C. J., Introduction to Neurology, 118
Herskovits, M. J., The Anthropometry of the American Negro, 357
Hess, W. R., The Technique of Local Stimulation of the Brain, 490
Heterochrony, 94
Hillier, W. T., A Theory of the Formation of Animals, 474
Himes, N. E., The Truth about Birth Control, 247
Hinman, E. Harold, The Utilization of Water Colloids and Material in Solution by Aquatic Animals with Especial Reference to Mosquito Larvae, 210–217
Hirsch, N. D. M., Genius and Creative Intelligence, 109
Hjort, J., The Emperor's New Clothes, 225
Hoffmann, H., Guide to Histological Investigation on Invertebrates and Vertebrates, 366
Hogben, L., Genetic Principles in Medicine and Social Science, 477
Holland-Rantos Co., Improved Guide for the Fitting and Use of Holland-Rantos Diaphragms, 123
Hooton, E. A., Up from the Ape, 101

Hornet nest, population of, 197
Hottes, F. C., and Frison, T. H., The Plant Lice, or Aphiidae, of Illinois, 236
Howard, L. O., The Insect Menace, 239
Howell, A. H., Florida Bird Life, 360
Hoyt, V. J., Bar-Rac: The Biography of a Raccoon, 115
Huber, E., Evolution of Facial Musculature and Facial Expression, 118
HUMAN BIOLOGY (book reviews), 105, 227, 39, 481
Humidity and density of population, 31
Hunter, G. W., Problems in Biology, 105
Huxley, A., Brave New World, 353
Hydatina senta, cell constancy in, 62
Hyde Genealogy, 77

Identity, law of, 397
Iltis, H., Life of Mendel, 477
Imms, A. D., Social Behavior in Insects, 239
INGALLS, N. WILLIAM, Some Developmental Risks: The Dorsal Mid-Line, 47–58
Ingles, L. G., Four New Species of Haematolocchus (Trematoda), an *Cephalogonimus brevicirrus*, a New Species of Trematode, 363
Inheritance of duration of life, 77
Intensity of activity and senescence, 72
Irritation and cancer, 256
Islands, oceanic, biological peculiarities of, 405

Jaeger, E. C., A Dictionary of Greek and Latin Combining Forms Used in Zoölogical Names, 238
James, W. O., An Introduction to Plant Physiology, 241
Jeffreys, H., Scientific Inference, 123
Johnstone, J., The Essentials of Biology, 480
Jollos, V., Genetics and the Evolution Problem, 224
Journal of Animal Ecology, 484
Joyet-Lavergne, Ph., The Physico-chemical Theory of Sex, 370

Kahn, E., Psychopathic Personalities, 496
Kaila, E. E., Tar-Burning in Finland in the Middle of the 18th Century, 365
Kanus, H., Paramecium, 361
Kangas, E., Damage to Pines in Siikakangas, 365
Kanner, L., Judging Emotions from Facial Expressions, 125
Kease, A., The Influence of Nutrition on the Constitution of the Organism, 246
Kenan, M. F., The Eocene Sierra Blanca Limestone, 476
Keith, A., New Discoveries Relating to the Antiquity of Man, 105
Keler, A. G., Societal Evolution, 345
Keley, D. G., *et al.*, Three Scout Naturalists in the National Parks, 240
Khalil, M., The Bibliography of Schistosomiasis, 361
Kidney, physiology of, 7, 17
Kig, V. and P., Looking Inwards, 235
Kirby, H., Jr., Flagellates of the Genus Trichonympha in Termites, 484
Kluger, J., Methuselahs of the Animal World, 480
Kofoid, C. A., and Mac Lennan, R. F., Ciliates from *Bos indicus* Linn., 363
Korschelt, E., Regeneration and Transplantation, 226, 480
Kostytschew, S., and Went, F.A.F.C., Plant Physiology, 364
Krabbe, Th. N., Greenland, Its Nature, Inhabitants, and History, 113
Krafft, C. F., Can Science Explain Life? 105
Krogh, A., Human Physiology, 490
Kuczynski, R. R., The Balance of Births and Deaths, 234
Kuntz, A., A Text-Book of Neuro-anatomy, 242
Kurtz, E. B., Life Expectancy of Physical Property, 250

Lacroix, P., History of Prostitution, 492
Laird, D. A., Why We Don't Like People, 495
Landman, J. H., Human Sterilization, 493
Lasseur, Ph., and Vernier, P., Works of the Laboratory of Microbiology of the Faculty of Pharmacy of Nancy, 119
Lassila, I., 365
League of Nations, Health Organization, Statistics of Notifiable Diseases for 1929, 357
LE BUFFE, FRANCIS P., God Means Anything Today, 340–344
Lenz, F., Ecology, 348
Leopold, A., Report on a Game Survey of the North Central States, 115
Lepidoptera, sex differential mortality in, 317
Leslie, L. A. D., Wilderness Trails in Three Continents, 237
Levene, P. A., and Bass, L. W., Nucleic Acids, 246
Lewin, L., Phantastica: Narcotic and Stimulating Drugs, 244
Leyburn, J. G., Handbook of Ethnography, 107
Library of Congress, Report for 1931, 376
Lillie's modification of the recapitulation theory, 95
Lindsey, A. W., A Textbook of Genetics, 478
Lindworsky, J., Experimental Psychology, 124
LINK, GEORGE K. K., The Rôle of Genetics in Etiological Pathology, 127–171
Little, M. E., Structure of the Vertebrates, 487
Loewy, A., Climatophysiology, 246
Loss of activity of body cells and catalysts with time, 69
Low temperatures, effect of on bacteria, 190

Luck, J. M. (Ed.), Annual Review of Biochemistry, 491
Ludwig, W., The Right-Left Problem in Animals and Man, 477
Lumbo-sacral region, vulnerability of, 57
Lundborg, H., Race Mixture in Man, 476
Lundegårdh, H., Environment and Plant Development, 117

Mac Arthur, John W., and Baillie, W. H. T., Sex Differences in Mortality in Abraxas-type Species, 313–325
Macklin, Madge Thurlow, The Hereditary Factor in Human Neoplasms, 255–281
Mahaim, I., The Organic Diseases of the Bundle of His-Tawara, 369
Major, R. H., The Doctor Explains, 245
Marett, R. R., and Penniman, T. K. (Ed.), Spencer's Scientific Correspondence, 481
Marie-Victorin, Frère, The Spadiciflora of Quebec, 365
Markowski, B., The Material Culture of the Kabul Region, 354
Martiny, M., *et al.*, Biological Specificity, 479
Matthews, V. D., Studies on the Genus Pythium, 117
McAllister, W. G., A Further Study of the Delayed Reaction in the Albino Rat, 374
McAtee, W. L., Effectiveness in Nature of the So-called Protective Adaptations in the Animal Kingdom, etc., 345
McDowell, S. A., Biology and Mankind, 223
McEwen, R. S., Vertebrate Embryology, 366
McSpadden, J. W., To the Ends of the World and Back, 239
Meckel's parallelism theory, 93
Meier, W. H. D., and Meier, D., Biology Notebook, 105
Mendelian inheritance, 142
Messenger, E. C., Evolution and Theology, 474
Metcalf, C. L., and Flint, W. P., Fundamentals of Insect Life, 361
Metcalf, Z. P., General Catalogue of the Hemiptera, 484
Microclimate, 28
Middleton, A. D., The Grey Squirrel, 357
Miller, A. H., Systematic Revision and Natural History of the American Shrikes (Lanius), 238
Miller, J., Jungles Preferred, 227
Millot, J., Cicatrization and Regeneration, 349
Miner, John R., The Cost of Biological Books in 1932, 498–499
Moench, G. L., Studies on Fertility, 122
Molisch, H., Botanical Experiments without Apparatus, 241
Montessus de Ballore, R. de, Probabilities and Statistics, 250
Moore, E. R., The Case Against Birth Control, 247
Moore, F. J., History of Chemistry, 121
Moorehead, W. K., Archaeology of the Arkansas River Valley, 112
Mores, 90
Morphology (book reviews), 117, 242, 365, 486
Mortality, sex differences in, in Abraxas-type species, 313
Mortara, G., Summary of Statistics, 249
Mosquito larvae, utilization of water colloids by, 210
Mottier, D. M., A Textbook of Botany for College Students, 484
Murchison, C. (Ed.), A History of Psychology in Autobiography, 375
Murray, L. W. (Ed.), Selected Manuscripts of General John S. Clark Relating to the Aboriginal History of the Susquehanna, 354

Nachtsheim, H. (Ed.), Transactions of First International Rabbit Breeders' Congress, 224
Needham, J., Chemical Embryology, 349, 469
Neoplasms, hereditary factor in, 255
New Biological Books, 100–125, 218–253, 340–376, 469–497
Newburgh, L. H., and Johnston, M. W., The Exchange of Energy between Man and the Environment, 246
Newell, J. M., and McCollum, E. V., Spectrographic Analysis of Marine Products, 122
Newman, H. H., Evolution Yesterday and Today, 475
Nice, M. M., The Birds of Oklahoma, 240
Niceforo, A., The Statistical Method, 372
Nissen, H. W., A Field Study of the Chimpanzee, 250
Noble, G. K., The Biology of the Amphibia, 37
Non-functional standards in breeding, 84
Non-Mendelian inheritance, 143
Nord, F. F., and Weidenhagen, R. (Ed.), Results of Enzyme Research, 369
Norden, H., A Wanderer in Indo-China, 351
Normal and abnormal, 135
Nyèssen, D. J. H., The Races of Java, 109
Somatical Investigation of the Javanese, 242

Okland, F., Will It Be a Boy?, 493
Onslow, M. W., The Principles of Plant Biochemistry, 241
Ontology, 386
Opie, E. L. Childhood Type of Tuberculosis, 119
Organizator theory, 97
Osborn, H. F., The Titanotheres of Ancient Wyoming, Dakota, and Nebraska, 100
Osmotic pressure of blood of vertebrates, 5

Ostenfeld, J., *et al.*, Tuberculosis in Denmark, Norway and Sweden, 120

Parasites, overemphasis of their rôle, 129
Parker, G. H., Humoral Agents in Nervous Activity, 488
Parmalee, M., Nudism in Modern Life, 229
Partial cell constancy, 63
Pasteurization of milk, 186
Patch, E. M., Holiday Hill, 227
and Howe, H. E., Hunting, 479
Outdoor Visits, 479
Paterson, D. G., Physique and Intellect, 355
Pathic genes, 145
Pathology as biological science, 131
and genetics, 127
Paul, J. H., The Last Cruise of the Carnegie, 480
Pearse, I. H., and Williamson, G. S., The Case for Action, 108
Peirce, G. J., Experimental Plant Physiology, 364
Perbal, L., The Utilization of the Bony Framework by Vertebrates, 476
Perrier, E., and Perrier, R., Zoology, 362
Peters, J. L., Check-List of Birds of the World, 360
Peterson, H., Huxley, 351
Petran, L. A., An Experimental Study of Pitch Recognition, 497
Philibert, A., Medical Bacteriology, 369
Phylogeny and eutely, 61
Physiology and Pathology (book reviews), 118, 243, 366, 488
Physiology and pathology, 139
Pickwell, G. B., The Prairie Horned Lark, 359
Pidgeon, M. E., Women in Industry, 112
Pigeon breeding, 86
Piney, A. (Ed.), Recent Advances in Microscopy: Biological Applications, 102
Pitkin, W. B., A Short Introduction to the History of Human Stupidity, 495
Pitt, J. N. U., Curiosities of Heredity, "The Hapsburg Lip," 224
Piza, S. de T., Jr., and Torres, A. P., Mitosis in Races of *Nothoscordum fragrans*, 117
Plarr, V. G., Lives of the Fellows of the Royal College of Surgeons of England, 107
Plasticity, ecological, 36
Poirier, P., and Charpy, A., Human Anatomy, 487
Population of hornet nest, 197
Populations, ecology of, 27
Power, D'A, The Foundations of Medical History, 234
Pressey, L. C., and Ferguson, J. M., Students' Guide to Efficient Study, 125
Price, G. Mc. C., The Geological-Ages Hoax, 218
Pringsheim, H., The Chemistry of the Monosaccharides and Polysaccharides, 491
Psychology and Behavior (book reviews), 124, 250, 373, 493
Pycraft, W. P. (Ed.), The Standard Natural History, 239

Quayle, E. H., Fossil Corals of the Genus Turbinolia, 476

Rahn, O., Physiology of Bacteria, 485
Ranald, J., Hands of Destiny, 235
Randoin, L., and Simmonet, H., The Vitamins, 368
Rawitscher, F., Geotropism of Plants, 486
Recapitulation theory, 93
Reed, J. A., The Rape of Temperance, 113
Reid, E. G., The Great Physician, 112
Reinheimer, H., Deliverance from Cancer, 120
Review of the Effects of Alcohol on Man, 230
Reynolds, E., The Evolution of the Human Pelvis, etc., 356
Reynolds, T. E., Hydrostatics of the Suctorial Mouth of the Lamprey, 113
Rich, W. H., and Bull, E. M., Statistical Review of the Alaska Salmon Fisheries, 362
Richards, A., Outline of Comparative Embryology, 242
Richards, E. L., Behaviour Aspects of Child Conduct, 494
Riley, W. A., and Johannsen, O. A., Medical Entomology, 360
Ritter, Wm. E., Why Aristotle Invented the Word Entelecheia, 377–404
Roberts, F. H. H., Jr., The Ruins at Kiatuthlanna, Eastern Arizona, 112
Robertson, C., Flowers and Insects, 236
Robertson-Miller, E., Butterfly and Moth Book, 239
Robinson, V., Pathfinders in Medicine, 352
The Story of Medicine, 352
Ronhaar, J. H., Woman in Primitive Motherright Societies, 353
Roome, W. J. W., Through the Lands of Nyanza, 235
Roosting habit of bats, 307
Ross, E. D. (Ed.), The Art of Egypt through the Ages, 356
Rosenberg, M., Sodomy's Best Liberator, 497
Rostand, J., The Evolution of Species, 474
Round, J. H., Family Origins, 233
Rouvière, H., Anatomy of the Lymphatics of Man, 487
Rowan, W., The Riddle of Migration, 240
Rubinow, I. M. (Ed.), The Care of the Aged, 235
Russell, B., The Scientific Outlook, 252
Russell, E. J., Soil Conditions and Plant Growth, 364

St. Helena, biota of, 413
Saller, K., Human Genetics and Eugenics, 478
Salt cycle of fishes, 9
Sanders, J., The Declining Birth Rate in Rotterdam, 355
Sanderson, E. D., and Peairs, L. M., Insect Pests of Farm, Garden and Orchard, 362
Sanger, M., My Fight for Birth Control, 247
and Stone, H. M., The Practice of Contraception, 371
Sarton, G., Introduction to the History of Science, 376
Scheidt, W., Race in Northern Europe, 234
Schieffelin, B., and Schwesinger, G. C., Mental Tests and Heredity, 346
Schiff, F., The Technique of Blood Grouping, 478
Schmidt, F. A., and Kohlrausch, W., Physiology of Exercise, 368
Schmidt, P., The Conquest of Old Age, 249
Schnack, F., The Life of the Butterfly, 362
Schweitzer, A., On the Edge of the Primeval Forest, 227
Selous, E., Thought-Transference (or What?) in Birds, 124
Senescence, 68
Sensitivity of fishes to sound, 326
Seward, A. C., Plants, 485
Plant Life through the Ages, 101
Sex (book reviews), 122, 247, 370, 492
Sex differences in mortality in Abraxas-type species, 313
Shapiro, H. L., The Physical Characters of the Society Islanders, 108
Sherman, H. C., and Smith, S. L., The Vitamins, 120
Shirley, M. M., The First Two Years, 106
Showerman, G., Rome and the Romans, 481
Shreve, F., The Cactus and Its Home, 364
Shull, A. F., Heredity, 102
Shumway, W., General Biology, 104
Shumway, Waldo, The Recapitulation Theory, 93–99
Siam: Nature and Industry, 233
Sigerist, H. E., Man and Medicine, 481
Similarity as criterion of identical twins, 299
Simpson, C. T., Florida Wild Life, 348
Singer, C., A Short History of Biology, 102
The Story of Living Things, 102
Skaggs, E. B., The Major Forms of Inhibition in Man, 251
Smith, H. W., Kamongo, 348
Smith, Homer W., Water Regulation and its Evolution in the Fishes, 1–26
Smith, M. A., The Fauna of British India, 237
Smith, W. B., The Jones Cove Shell Heap at West Gouldsboro, Maine, 232
The Lost Red Paint People of Maine, 232
Snails, colonization of, 414
Sorsby, M., Cancer and Race, 223
Sound, sensitivity of fishes to, 326
stimuli, 444
Spaeth, L. M., Marriage and Family Life among Strange Peoples, 235
Spahr, W. E., and Swenson, R. J., Methods and Status of Scientific Research, 113
Spence, K. W., The Reliability of the Maze and Methods of Its Determination, 495
Spiller, G., The Origin and Nature of Man, 222
Stability, germinal, 48
Stahl, F. A., Origin of Cancer, 369
Starks, E. C., and Cutter, R. D., The Dissection of the Rat, 118
Sterility as a pathic event, 147
Stern, E., Beginnings of Old Age, 119
Stoklasa, J., and Pěnkava, J., Biology of Radium and Radioactive Elements, 479
Stopes, M. C., Married Love, 122
Strong, E. K., Jr., Change of Interests with Age, 250
Sturtevant, A. H., and Dobzhansky, T., Contributions to the Genetics of Certain Chromosome Anomalies in *Drosophila melanogaster*, 346
Svensgaard, E., Blood Sugar in Normal and Sick Children, 368
Sweet, H., The History of Language, 375
Swift, E. J., The Jungle of the Mind, 251

Tamagawa, K., Holy Prayers in a Horse's Ear, 356
Tattersall, W. M., Contributions to a Knowledge of the Mysidacea of California, 484
Telos, 380
Temperature and aging of body cells, 72
and density of population, 30, 37
its influence on bacteria, 172
relations of seed germination, 428
Thayer, W. S., Osler and Other Papers, 355
Thermal death points of bacteria, 175
Thiel, R., Men Against Death and the Devil, 231
Thomson, J. A., Purpose in Evolution, 475
and Geddes, P., Life: Outlines of General Biology, 225
Thorndike, E. M., Reward and Punishment in Animal Learning, 375
Thurstone, L. L., and Jenkins, R. L., Order of Birth, Parent-Age, and Intelligence, 106
Tolman, E. C., Purposive Behavior in Animals and Men, 493
Torrey, R. E., General Botany for Colleges, 484
Tothill, J. D., *et al.*, The Coconut Moth in Fiji, 358
Townsend, C. H., Where the Nineteenth Century Whaler Made His Catch, 363
Trematodes, classification, 458

Troland, L. T., The Principles of Psychophysiology, 497
Trout, D. M., Religious Behavior, 374
Turner, C. W., The Anatomy of the Mammary Gland of Cattle, 367
The Development of the Mammary Gland, 367
and Gardner, W. U., The Relation of the Anterior Pituitary Hormones to the Development and Secretion of the Mammary Gland, 367
and Herman, H. A., A Determination of the Blood and Plasma Volume of Dairy Cattle, 367
and Schultze, A. B., A Study of the Causes of the Normal Development of the Mammary Glands of the Albino Rat, 367
Twins, modern research on, 298
Tzanck, A., Immunity, Intolerance, Biophylaxis, 347

Uremia of elasmobranchs, 12
Urine, excretion of, 6
U. S. Department of Commerce, Bureau of the Census, Marriage and Divorce 1930, 350
Manual of the International List of Causes of Death, 357
U. S. Department of Labor, Children's Bureau, Child Welfare in Selected Counties of Washington, 234
Juvenile-Court Statistics 1929, 113
The Child from One to Six, 110
Uvarov, B. P., Insects and Climate, 114

Van Cleave, H. J., Invertebrate Zoölogy, 115
Van Cleave, Harley J., Eutely or Cell Constancy in its Relation to Body Size, 59–67
Van Riper, Walker, Aesthetic Notions in Animal Breeding, 84–92
Variability, germinal, 48
Vecki, V. G., Prevention of Premature Senility, 245
Vespa maculata, 197
Vigneron, H., Manual of Laboratory Calculations, 372
Vulnerability of dorsal mid-line, 52

Waksman, S. A., Principles of Soil Microbiology, 364
Waldron, M., Snow Man, 354
Walford, L. A., Handbook of Common Commercial and Game Fishes of California, 116
Walker, C. C., The Biology of Civilization, 228
Warden, C. J., The Evolution of Human Behavior, 475
Warner, Lucien H., The Sensitivity of Fishes to Sound and to Other Mechanical Stimulation, 326–339
Water colloids, utilization of, by aquatic animals, 210
regulation in the fishes, 1
Waterman, W. C., Prostitution and Its Repression in New York City, 492
Weiss, P., From the Workshops of Biological Research, 227
Wetmore, A., and Swales, B. H., The Birds of Haiti and the Dominican Republic, 114
Weygandt, C., The Wissahickon Hills, 103
Wheeler, G. C., A Bibliography of the Sardines, 363
White, E. I., The Vertebrate Faunas of the English Eocene, 223
White, W. A., Medical Psychology, 125
von Wiesner, J., *et al.*, Raw Materials of the Plant Realm, 122
Williams, R. J., Introduction to Biochemistry, 121
Wingate, S. D., The Mediaeval Latin Versions of the Aristotelian Scientific Corpus, 227
Winslow, C.-E. A., Health on the Farm and in the Village, 108
Wislocki, George B., Biochemistry and Development, 469–473
Woker, G., Catalysis, 246
Wolda, G., Periodicity, Rhythm and Symmetry with the Births, 111
Wolff, G., The Aftereffect of War Starvation on the Growth of School Children, 356
Woltereck, R., Foundations of a General Biology, 478
Woodruff, L. L., Animal Biology, 483
Work, M. N. (Ed.), Negro Year Book, 231
Wright, A. H., Life-Histories of the Frogs of the Okefinokee Swamps, Georgia, 359
v. Wyss, W. H., The Relation of Body and Mind in Health and Disease, 373

Yates, D. H., Psychological Racketeers, 496
Yeast populations, growth of, 39
Yerkes, R. M., Yale Laboratories of Comparative Psychobiology, 374
Yuan, I-Chin, A Critique of Certain Earlier Work on the Inheritance of Duration of Life in Man, 77–83

"Zeitfänge" index of density of population, 29
Zoölogy (book reviews), 113, 236, 357, 482
Zuckerman, S., The Social Life of Monkeys and Apes, 361